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BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)
BACKGROUND DOCUMENT FOR
K024

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EXECUTIVE SUMMARY

BDAT Treatment Standards for K024

Pursuant to section 3004(m) of the Resource Conservation and Recovery Act as enacted by the Hazardous and Solid Waste Amendments on November 8, 1984, the Environmental Protection Agency (EPA) is establishing best demonstrated available technology (BDAT) treatment standards for the listed waste identified in 40 CFR 261.32 as K024. Compliance with these BDAT treatment standards is a prerequisite for placement of the waste in units designated as land disposal units according to 40 CFR Part 268. The effective date of these treatment standards is August 8, 1988.

This background document provides the Agency's rationale and technical support for selecting the constituents to be regulated in K024 waste and for developing treatment standards for those regulated constituents. The document also provides waste characterization and treatment information that serves as a basis for determining whether variances may be warranted. EPA may grant a treatment variance in cases where the Agency determines that the waste in question is more difficult to treat than the wastes upon which the BDAT treatment standards are based.

The introductory section, which appears verbatim in all the First Third background documents, summarizes the Agency's legal authority and promulgated methodology for establishing treatment standards and discusses the petition process necessary for requesting a variance from the treatment standards. The remainder of the document presents waste-specific information--the number and locations of facilities affected by the land disposal restrictions for K024 waste, the waste-generating process, waste characterization data, the technologies used to treat the waste (or similar wastes), and available performance data, including data on which the treatment standards are based. The document also explains EPA's determination of BDAT, selection of constituents to be regulated, and calculation of treatment standards.

It is EPA's understanding that only one facility produces phthalic anhydride, using naphthalene as a feedstock.

The Agency is regulating one organic constituent in both nonwastewater and wastewater forms of K024. (For the purpose of determining the applicability of the treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Waste not meeting this definition must comply with the treatment standards for nonwastewaters.)

A treatment standard is established for one organic constituent, phthalic acid, which the Agency believes is an indicator of effective treatment for the BDAT hazardous constituent phthalic anhydride.

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*The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Specifically, total suspended solids is measured by method 209C. (Total Suspended Solids Dried at 103-205°C) in Standard Methods for the Examination of Water and Wastewater, 16th Edition.

Phthalic acid is chosen as the surrogate constituent to be regulated because phthalic anhydride cannot be easily analyzed. (During chemical analysis, phthalic anhydride undergoes hydrolysis to produce phthalic acid.) Phthalic acid is chosen as a surrogate treatment evaluation parameter since its precursor, phthalic anhydride, which is a BDAT constituent, is present at treatable concentrations in the waste. This standard is for the total concentration of phthalic acid measured in K024 waste.

BDAT standards for wastewaters and nonwastewaters have been established based on actual performance data using rotary kiln incineration.

The following table presents the treatment standards for K024 wastewater and nonwastewater. The treatment standards are established based on total concentration analyses conducted on the total (untreated) waste, ash residues, and scrubber water generated during rotary kiln incineration of K024. If the concentrations of the regulated constituents in K024 waste, as generated, are lower than or equal to the proposed BDAT treatment standards, then treatment is not necessary as a prerequisite to land disposal.

Testing procedures are specifically identified in Appendix B of this background document.

BDAT Treatment Standards for K024

Constituent	Maximum for any single grab sample		
	Nonwastewater		Wastewater
	Total concentration (mg/kg)	TCLP leachate concentration (mg/l)	Total concentration (mg/l)
Phthalic acid[a]	28	NA	0.54

NA = Not applicable.

[a] This constituent is regulated as a surrogate for phthalic anhydride, which cannot be easily analyzed because it is hydrolyzed and converted to phthalic acid during chemical analysis.

1. INTRODUCTION

This section of the background document presents a summary of the legal authority pursuant to which the best demonstrated available technology (BDAT) treatment standards were developed, a summary of EPA's promulgated methodology for developing the BDAT treatment standards, and, finally, a discussion of the petition process that should be followed to request a variance from the BDAT treatment standards.

1.1 Legal Background

1.1.1 Requirements Under HSWA

The Hazardous and Solid Waste Amendments of 1984 (HSWA), which were enacted on November 8, 1984, and which amended the Resource Conservation and Recovery Act of 1976 (RCRA), impose substantial new responsibilities on those who handle hazardous waste. In particular, the amendments require the Agency to promulgate regulations that restrict the land disposal of untreated hazardous wastes. In its enactment of HSWA, Congress stated explicitly that "reliance on land disposal should be minimized or eliminated, and land disposal, particularly landfill and surface impoundment, should be the least favored method for managing hazardous wastes" (RCRA section 1002(b)(7), 42 U.S.C. 6901(b)(7)).

One part of the amendments specifies dates on which particular groups of untreated hazardous wastes will be prohibited from land disposal unless "it has been demonstrated to the Administrator, to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous" (RCRA section 3004(d)(1), (e)(1), (g)(5), 42 U.S.C. 6924 (d)(1), (e)(1), (g)(5)).

For the purpose of the restrictions, HSWA defines land disposal "to include, but not be limited to, any placement of . . . hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave" (RCRA section 3004(k), 42 U.S.C. 6924(k)). Although HSWA defines land disposal to include injection wells, such disposal of solvents, dioxins, and certain other wastes, known as the California List wastes, is covered on a separate schedule (RCRA section 3004(f)(2), 42 U.S.C. 6924 (f)(2)). This schedule requires that EPA develop land disposal restrictions for deep well injection by August 8, 1988.

The amendments also require the Agency to set "levels or methods of treatment, if any, which substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short-term and long-term threats to human health and the environment are minimized" (RCRA section 3004(m)(1), 42 U.S.C. 6924 (m)(1)). Wastes that satisfy such levels or methods of treatment established by EPA, i.e., treatment standards, are not prohibited from being land disposed.

In setting treatment standards for listed or characteristic wastes, EPA may establish different standards for particular wastes within a single waste code with differing treatability characteristics. One such characteristic is the physical form of the waste. This frequently leads to different standards for wastewaters and nonwastewaters. Alternatively, EPA can establish a treatment standard that is applicable to more than one waste code when, in EPA's judgment, a particular constituent present in the wastes can be treated to the same concentration in all the wastes.

In those instances where a generator can demonstrate that the standard promulgated for the generator's waste cannot be achieved, the amendments allow the Agency to grant a variance from a treatment standard by revising the treatment standard for that particular waste through rulemaking procedures. (A further discussion of treatment variances is provided in Section 1.3.)

The land disposal restrictions are effective when promulgated unless the Administrator grants a national variance and establishes a different date (not to exceed 2 years beyond the statutory deadline) based on "the earliest date on which adequate alternative treatment, recovery, or disposal capacity which protects human health and the environment will be available" (RCRA section 3004(h)(2), 42 U.S.C. 6924 (h)(2)).

If EPA fails to set treatment standards by the statutory deadline for any hazardous waste in the First Third or Second Third waste groups (see Section 1.1.2), the waste may not be disposed in a landfill or surface impoundment unless the facility is in compliance with the minimum technological requirements specified in section 3004(o) of RCRA. In addition, prior to disposal, the generator must certify to the Administrator that the availability of treatment capacity has been investigated, and it has been determined that disposal in a landfill or surface impoundment is the only practical alternative to treatment currently available to the generator. This restriction on the use of landfills and surface impoundments applies until EPA sets treatment standards for the waste or until May 8, 1990, whichever is sooner. If the Agency fails to set treatment standards for any ranked hazardous waste by May 8, 1990, the waste is automatically prohibited from land disposal unless the waste is placed in a land disposal unit that is the subject of a successful "no migration" demonstration (RCRA section 3004(g), 42 U.S.C. 6924(g)). "No migration" demonstrations are based on case-specific petitions that show there will be no migration of hazardous constituents from the unit for as long as the waste remains hazardous.

1.1.2 Schedule for Developing Restrictions

Under section 3004(g) of RCRA, EPA was required to establish a schedule for developing treatment standards for all wastes that the Agency had listed as hazardous by November 8, 1984. Section 3004(g) required that this schedule consider the intrinsic hazards and volumes associated with each of these wastes. The statute required EPA to set treatment standards according to the following schedule:

1. Solvent and dioxin wastes by November 8, 1986;
2. The "California List" wastes by July 8, 1987;
3. At least one-third of all listed hazardous wastes by August 8, 1988 (First Third);

4. At least two-thirds of all listed hazardous wastes by June 8, 1989 (Second Third); and

5. All remaining listed hazardous wastes and all hazardous wastes identified as of November 8, 1984, by one or more of the characteristics defined in 40 CFR Part 261 by May 8, 1990 (Third Third).

The statute specifically identified the solvent wastes as those covered under waste codes F001, F002, F003, F004, and F005; it identified the dioxin-containing hazardous wastes as those covered under waste codes F020, F021, F022, and F023.

Wastes collectively known as the California List wastes, defined under section 3004(d) of HSWA, are liquid hazardous wastes containing metals, free cyanides, PCBs, corrosives (i.e., a pH less than or equal to 2.0), and any liquid or nonliquid hazardous waste containing halogenated organic compounds (HOCs) above 0.1 percent by weight. Rules for the California List were proposed on December 11, 1986, and final rules for PCBs, corrosives, and HOC-containing wastes were established August 12, 1987. In that rule, EPA elected not to establish treatment standards for metals. Therefore, the statutory limits became effective.

On May 28, 1986, EPA published a final rule (51 FR 19300) that delineated the specific waste codes that would be addressed by the First Third, Second Third, and Third Third land disposal restriction rules. This schedule is incorporated into 40 CFR 268.10, 268.11, and 268.12.

1.2 Summary of Promulgated BDAT Methodology

In a November 7, 1986, rulemaking, EPA promulgated a technology-based approach to establishing treatment standards under section 3004(m).

Congress indicated in the legislative history accompanying the HSWA that "[t]he requisite levels of [sic] methods of treatment established by the Agency should be the best that has been demonstrated to be achievable," noting that the intent is "to require utilization of available technology" and not a "process which contemplates technology-forcing standards" (Vol. 130 Cong. Rec. S9178 (daily ed., July 25, 1984)). EPA has interpreted this legislative history as suggesting that Congress considered the requirement under section 3004(m) to be met by application of the best demonstrated and achievable (i.e., available) technology prior to land disposal of wastes or treatment residuals. Accordingly, EPA's treatment standards are generally based on the performance of the best demonstrated available technology (BDAT) identified for treatment of the hazardous constituents. This approach involves the identification of potential treatment systems, the determination of whether they are demonstrated and available, and the collection of treatment data from well-designed and well-operated systems.

The treatment standards, according to the statute, can represent levels or methods of treatment, if any, that substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents. Wherever possible, the Agency prefers to establish BDAT treatment standards as "levels" of treatment (i.e., performance standards), rather than to require the use of specific treatment "methods." EPA believes that concentration-based treatment levels offer the regulated community greater flexibility to develop and implement compliance strategies, as well as an incentive to develop innovative technologies.

1.2.1 Waste Treatability Group

In developing the treatment standards, EPA first characterizes the waste(s). As necessary, EPA may establish treatability groups for wastes having similar physical and chemical properties. That is, if EPA believes that hazardous constituents in wastes represented by different waste codes could be treated to similar concentrations using identical technologies, the Agency combines the wastes into one treatability group. EPA generally considers wastes to be similar when they are both generated from the same industry and from similar processing stages. In addition, EPA may combine two or more separate wastes into the same treatability group when data are available showing that the waste characteristics affecting performance are similar or that one of the wastes in the group, the waste from which treatment standards are to be developed, is expected to be most difficult to treat.

Once the treatability groups have been established, EPA collects and analyzes data on identified technologies used to treat the wastes in each treatability group. The technologies evaluated must be demonstrated on the waste or a similar waste and must be available for use.

1.2.2 Demonstrated and Available Treatment Technologies

Consistent with legislative history, EPA considers demonstrated technologies to be those that are currently used on a full-scale basis to treat the waste of interest or a waste judged to be similar (see 51 FR 40588, November 7, 1986). EPA also will consider as demonstrated treatment those technologies used to separate or otherwise process chemicals and other materials on a full-scale basis. Some of these technologies clearly are applicable to waste treatment, since the wastes are similar to raw materials processed in industrial applications.

For most of the waste treatability groups for which EPA will promulgate treatment standards, EPA will identify demonstrated technologies either through review of literature related to current waste treatment practices or on the basis of information provided by specific facilities currently treating the waste or similar wastes.

In cases where the Agency does not identify any facilities treating wastes represented by a particular waste treatability group, EPA may transfer a finding of demonstrated treatment. To do this, EPA will compare the parameters affecting treatment selection for the waste treatability group of interest to other wastes for which demonstrated technologies already have been determined. (The parameters affecting treatment selection and their use for this waste are described in Section 3.2 of this document.) If the parameters affecting treatment selection are similar, then the Agency will consider the treatment technology also to be demonstrated for the waste of interest. For example, EPA considers rotary kiln incineration to be a demonstrated technology for many waste codes containing hazardous organic constituents, high total organic content, and high filterable solids content, regardless of whether any facility is currently treating these wastes. The basis for this determination is data found in literature and data generated by EPA confirming the use of rotary kiln incineration on wastes having the above characteristics.

If no full-scale treatment or recovery operations are identified for a waste or wastes with similar physical or chemical characteristics that affect treatment selection, the Agency will be unable to identify any demonstrated treatment technologies for the waste, and, accordingly, the waste will be prohibited from land disposal (unless handled in accordance with the exemption and variance provisions of the rule). The Agency is, however, committed to establishing treatment standards as soon as new or improved treatment processes are demonstrated (and available).

Operations only available at research facilities, pilot- and bench-scale operations, will not be considered in identifying demonstrated treatment technologies for a waste. Nevertheless, EPA may use data generated at research facilities in assessing the performance of demonstrated technologies.

As discussed earlier, Congress intended that technologies used to establish treatment standards under section 3004(m) be not only "demonstrated," but also "available." To decide whether demonstrated technologies may be considered "available," the Agency determines whether they (1) are commercially available and (2) substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste. These criteria are discussed below.

1. Commercially available treatment. If the demonstrated treatment technology is a proprietary or patented process that is not generally available, EPA will not consider the technology in its determination of the treatment standards. EPA will consider proprietary or patented processes available if it determines that the treatment method can be purchased or licensed from the proprietor or is a commercially available treatment. The services of the commercial facility offering this technology often can be purchased even if the technology itself cannot be purchased.

2. Substantial treatment. To be considered "available," a demonstrated treatment technology must "substantially diminish the toxicity" of the waste or "substantially reduce the likelihood of migration of hazardous constituents" from the waste in accordance with section 3004(m). By requiring that substantial treatment be achieved in order to set a treatment standard, the statute ensures that all wastes are adequately treated before being placed in or on the land and ensures that the Agency does not require a treatment method that provides little or no environmental benefit. Treatment will always be deemed substantial if it results in nondetectable levels of the hazardous constituents of concern (provided the nondetectable levels are low relative to the concentrations in the untreated waste). If nondetectable levels are not achieved, then a determination of substantial treatment will be made on a case-by-case basis. This approach is necessary because of the difficulty of establishing a meaningful guideline that can be applied broadly to the many wastes and technologies to be considered. EPA will consider the following factors in an effort to evaluate whether a technology provides substantial treatment on a case-by-case basis:

   - Number and types of constituents treated;
   - Performance (concentration of the constituents in the treatment residuals); and
   - Percent of constituents removed.

EPA will only set treatment standards based on a technology that meets both availability criteria. Thus, the decision to classify a technology as "unavailable" will have a direct impact on the treatment standard. If the best demonstrated technology is unavailable, the treatment standards will be based on the next best demonstrated treatment technology determined to be available. To the extent that the resulting treatment standards are less stringent, greater concentrations of hazardous constituents in the treatment residuals could be placed in land disposal units.

There also may be circumstances in which EPA concludes that for a given waste none of the demonstrated treatment technologies are "available" for purposes of establishing the 3004(m) treatment performance standards. Subsequently, these wastes will be prohibited from continued placement in or on the land unless managed in accordance with applicable exemptions and variance provisions. The Agency is, however, committed to establishing new treatment standards as soon as new or improved treatment processes become available.

1.2.3 Collection of Performance Data

Performance data on the demonstrated available technologies are evaluated by the Agency to determine whether the data are representative of well-designed and well-operated treatment systems. Only data from well-designed and well-operated systems are considered in determining BDAT. The data evaluation includes data already collected directly by

EPA and/or data provided by industry. In those instances where additional data are needed to supplement existing information, EPA collects additional data through a sampling and analysis program. The principal elements of this data collection program are: (1) the identification of facilities for site visits, (2) the engineering site visit, (3) the sampling and analysis plan, (4) the sampling visit, and (5) the onsite engineering report.

(1) Identification of facilities for site visits. To identify facilities that generate and/or treat the waste of concern, EPA uses a number of information sources. These include Stanford Research Institute's Directory of Chemical Producers; EPA's Hazardous Waste Data Management System (HWDMS); the 1986 Treatment, Storage, Disposal Facility (TSDF) National Screening Survey; and EPA's Industry Studies Data Base. In addition, EPA contacts trade associations to inform them that the Agency is considering visits to facilities in their industry and to solicit their assistance in identifying facilities for EPA to consider in its treatment sampling program.

After identifying facilities that treat the waste, EPA uses this hierarchy to select sites for engineering visits: (1) generators treating single wastes on site; (2) generators treating multiple wastes together on site; (3) commercial treatment, storage, and disposal facilities (TSDFs); and (4) EPA in-house treatment. This hierarchy is based on two concepts: (1) to the extent possible, EPA should develop treatment standards from data produced by treatment facilities handling only a single waste, and (2) facilities that routinely treat a specific waste have had the best opportunity to optimize design parameters. Although excellent treatment can occur at many facilities that are not high in this hierarchy, EPA has adopted this approach to avoid, when possible, ambiguities related to the mixing of wastes before and during treatment.

When possible, the Agency will evaluate treatment technologies using full-scale treatment systems. If performance data from properly designed and operated full-scale systems treating a particular waste or a waste judged to be similar are not available, EPA may use data from research facility operations. Whenever research facility data are used, EPA will explain in the preamble and background document why such data were used and will request comments on the use of such data.

Although EPA's data bases provide information on treatment for individual wastes, the data bases rarely provide data that support the selection of one facility for sampling over another. In cases where several treatment sites appear to fall into the same level of the hierarchy, EPA selects sites for visits strictly on the basis of which facility could most expeditiously be visited and later sampled if justified by the engineering visit.

(2) Engineering site visit. Once a treatment facility has been selected, an engineering site visit is made to confirm that a candidate for sampling meets EPA's criteria for a well-designed facility and to

ensure that the necessary sampling points can be accessed to determine operating parameters and treatment effectiveness. During the visit, EPA also confirms that the facility appears to be well operated, although the actual operation of the treatment system during sampling is the basis for EPA's decisions regarding proper operation of the treatment unit. In general, the Agency considers a well-designed facility to be one that contains the unit operations necessary to treat the various hazardous constituents of the waste, as well as to control other nonhazardous materials in the waste that may affect treatment performance.

In addition to ensuring that a system is reasonably well designed, the engineering visit examines whether the facility has a way to measure the operating parameters that affect performance of the treatment system during the waste treatment period. For example, EPA may choose not to sample a treatment system that operates in a continuous mode, for which an important operating parameter cannot be continuously recorded. In such systems, instrumentation is important in determining whether the treatment system is operating at design values during the waste treatment period.

(3) Sampling and analysis plan. If after the engineering site visit the Agency decides to sample a particular plant, the Agency will then develop a site-specific sampling and analysis plan (SAP) according to the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011. In brief, the SAP discusses where the Agency plans to sample, how the samples will be taken, the frequency

of sampling, the constituents to be analyzed and the method of analysis, operational parameters to be obtained, and specific laboratory quality control checks on the analytical results.

The Agency will generally produce a draft of the site-specific SAP within 2 to 3 weeks of the engineering visit. The draft of the SAP is then sent to the plant for review and comment. With few exceptions, the draft SAP should be a confirmation of data collection activities discussed with the plant personnel during the engineering site visit. EPA encourages plant personnel to recommend any modifications to the SAP that they believe will improve the quality of the data.

It is important to note that sampling of a plant by EPA does not mean that the data will be used in the development of BDAT treatment standards. EPA's final decision on whether to use data from a sampled plant depends on the actual analysis of the waste being treated and on the operating conditions at the time of sampling. Although EPA would not plan to sample a facility that was not ostensibly well designed and well operated, there is no way to ensure that at the time of the sampling the facility will not experience operating problems. Additionally, EPA statistically compares its test data to suitable industry-provided data, where available, in its determination of what data to use in developing treatment standards. The methodology for comparing data is presented later in this section.

(Note: Facilities wishing to submit data for consideration in the development of BDAT standards should, to the extent possible, provide sampling information similar to that acquired by EPA. Such facilities should review the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), which delineates all of the quality control and quality assurance measures associated with sampling and analysis. Quality assurance and quality control procedures are summarized in Section 1.2.6 of this document.)

(4) Sampling visit. The purpose of the sampling visit is to collect samples that characterize the performance of the treatment system and to document the operating conditions that existed during the waste treatment period. At a minimum, the Agency attempts to collect sufficient samples of the untreated waste and solid and liquid treatment residuals so that variability in the treatment process can be accounted for in the development of the treatment standards. To the extent practicable, and within safety constraints, EPA or its contractors collect all samples and ensure that chain-of-custody procedures are conducted so that the integrity of the data is maintained.

In general, the samples collected during the sampling visit will have already been specified in the SAP. In some instances, however, EPA will not be able to collect all planned samples because of changes in the facility operation or plant upsets; EPA will explain any such deviations from the SAP in its follow-up onsite engineering report.

(5) Onsite engineering report. EPA summarizes all its data collection activities and associated analytical results for testing at a facility in a report referred to as the onsite engineering report (OER). This report characterizes the waste(s) treated, the treated residual concentrations, the design and operating data, and all analytical results including methods used and accuracy results. This report also describes any deviations from EPA's suggested analytical methods for hazardous wastes that appear in Test Methods for Evaluating Solid Waste, SW-846, Third Edition, November 1986.

After the OER is completed, the report is submitted to the waste generator and/or treater for review. This review provides a final opportunity for claiming any information contained in the report as confidential. Following the review and incorporation of comments, as appropriate, the report is made available to the public with the exception of any material claimed as confidential.

1.2.4 Hazardous Constituents Considered and Selected for Regulation

(1) Development of BDAT list. The list of hazardous constituents within the waste codes that are targeted for treatment is referred to by the Agency as the BDAT constituent list. This list, provided as Table 1-1, is derived from the constituents presented in 40 CFR Part 261, Appendices VII and VIII, as well as several ignitable constituents used as the basis of listing wastes as F003 and F005. These sources provide a

Table 1-1 BDAT Constituent List

BDAT reference no.	Constituent	CAS no.
	Volatile organics	
222.	Acetone	67-64-1
1.	Acetonitrile	75-05-8
2.	Acrolein	107-02-8
3.	Acrylonitrile	107-13-1
4.	Benzene	71-43-2
5.	Bromodichloromethane	75-27-4
6.	Bromomethane	74-83-9
223.	n-Butyl alcohol	71-36-3
7.	Carbon tetrachloride	56-23-5
8.	Carbon disulfide	75-15-0
9.	Chlorobenzene	108-90-7
10.	2-Chloro-1,3-butadiene	126-99-8
11.	Chlorodibromomethane	124-48-1
12.	Chloroethane	75-00-3
13.	2-Chloroethyl vinyl ether	110-75-8
14.	Chloroform	67-66-3
15.	Chloromethane	74-87-3
16.	3-Chloropropene	107-05-1
17.	1,2-Dibromo-3-chloropropane	96-12-8
18.	1,2-Dibromoethane	106-93-4
19.	Dibromomethane	74-95-3
20.	trans-1,4-Dichloro-2-butene	110-57-6
21.	Dichlorodifluoromethane	75-71-8
22.	1,1-Dichloroethane	75-34-3
23.	1,2-Dichloroethane	107-06-2
24.	1,1-Dichloroethylene	75-35-4
25.	trans-1,2-Dichloroethene	156-60-5
26.	1,2-Dichloropropane	78-87-5
27.	trans-1,3-Dichloropropene	10061-02-6
28.	cis-1,3-Dichloropropene	10061-01-5
29.	1,4-Dioxane	123-91-1
224.	2-Ethoxyethanol	110-80-5
225.	Ethyl acetate	141-78-6
226.	Ethyl benzene	100-41-4
30.	Ethyl cyanide	107-12-0
227.	Ethyl ether	60-29-7
31.	Ethyl methacrylate	97-63-2
214.	Ethylene oxide	75-21-8
32.	Iodomethane	74-88-4
33.	Isobutyl alcohol	78-83-1
228.	Methanol	67-56-1
34.	Methyl ethyl ketone	78-93-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Volatile organics (continued)	
229.	Methyl isobutyl ketone	108-10-1
35.	Methyl methacrylate	80-62-6
37.	Methacrylonitrile	126-98-7
38.	Methylene chloride	75-09-2
230.	2-Nitropropane	79-46-9
39.	Pyridine	110-86-1
40.	1,1,1,2-Tetrachloroethane	630-20-6
41.	1,1,2,2-Tetrachloroethane	79-34-6
42.	Tetrachloroethene	127-18-4
43.	Toluene	108-88-3
44.	Tribromomethane	75-25-2
45.	1,1,1-Trichloroethane	71-55-6
46.	1,1,2-Trichloroethane	79-00-5
47.	Trichloroethene	79-01-6
48.	Trichloromonofluoromethane	75-69-4
49.	1,2,3-Trichloropropane	96-18-4
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
50.	Vinyl chloride	75-01-4
215.	1,2-Xylene	97-47-6
216.	1,3-Xylene	108-38-3
217.	1,4 Xylene	106-44-5
	Semivolatile organics	
51.	Acenaphthalene	208-96-8
52.	Acenaphthene	83-32-9
53.	Acetophenone	96-86-2
54.	2-Acetylaminofluorene	53-96-3
55.	4-Aminobiphenyl	92-67-1
56.	Aniline	62-53-3
57.	Anthracene	120-12-7
58.	Aramite	140-57-8
59.	Benz(a)anthracene	56-55-3
218.	Benzal chloride	98-87-3
60.	Benzenethiol	108-98-5
61.	Deleted	
62.	Benzo(a)pyrene	50-32-8
63.	Benzo(b)fluoranthene	205-99-2
64.	Benzo(ghi)perylene	191-24-2
65.	Benzo(k)fluoranthene	207-08-9
66.	p-Benzoquinone	106-51-4

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
67.	Bis(2-chloroethoxy)methane	111-91-1
68.	Bis(2-chloroethyl)ether	111-44-4
69.	Bis(2-chloroisopropyl)ether	39638-32-9
70.	Bis(2-ethylhexyl)phthalate	117-81-7
71.	4 Bromophenyl phenyl ether	101 55-3
72.	Butyl benzyl phthalate	85-68-7
73.	2-sec-Butyl-4,6-dinitrophenol	88-85-7
74.	p-Chloroaniline	106-47-8
75.	Chlorobenzilate	510-15-6
76.	p-Chloro-m-cresol	59-50-7
77.	2-Chloronaphthalene	91-58-7
78.	2-Chlorophenol	95-57-8
79.	3-Chloropropionitrile	542-76-7
80.	Chrysene	218-01-9
81.	ortho-Cresol	95-48-7
82.	para-Cresol	106-44-5
232.	Cyclohexanone	108-94 1
83.	Dibenz(a,h)anthracene	53-70-3
84.	Dibenzo(a,e)pyrene	192-65-4
85.	Dibenzo(a,i)pyrene	189-55-9
86.	m Dichlorobenzene	541-73 1
87.	o-Dichlorobenzene	95-50-1
88.	p-Dichlorobenzene	106-46-7
89.	3,3'-Dichlorobenzidine	91-94-1
90.	2,4-Dichlorophenol	120-83 2
91.	2,6-Dichlorophenol	87-65-0
92.	Diethyl phthalate	84-66-2
93.	3,3'-Dimethoxybenzidine	119-90-4
94.	p Dimethylaminoazobenzene	60-11-7
95.	3,3'-Dimethylbenzidine	119-93-7
96.	2,4-Dimethylphenol	105-67-9
97.	Dimethyl phthalate	131-11-3
98.	Di-n-butyl phthalate	84-74-2
99.	1,4-Dinitrobenzene	100-25-4
100.	4,6-Dinitro-o-cresol	534-52-1
101.	2,4-Dinitrophenol	51-28-5
102.	2,4-Dinitrotoluene	121-14-2
103.	2,6-Dinitrotoluene	606-20-2
104.	Di-n-octyl phthalate	117-84-0
105.	Di-n-propylnitrosamine	621-64-7
106.	Diphenylamine	122-39-4
219.	Diphenylnitrosamine	86-30-6

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
107.	1,2-Diphenylhydrazine	122-66-7
108.	Fluoranthene	206-44-0
109.	Fluorene	86-73-7
110.	Hexachlorobenzene	118-74-1
111.	Hexachlorobutadiene	87-68-3
112.	Hexachlorocyclopentadiene	77-47-4
113.	Hexachloroethane	67-72-1
114.	Hexachlorophene	70-30-4
115.	Hexachloropropene	1888-71-7
116.	Indeno(1,2,3-cd)pyrene	193-39-5
117.	Isosafrole	120-58-1
118.	Methapyrilene	91-80-5
119.	3-Methylcholanthrene	56-49-5
120.	4,4'-Methylenebis (2-chloroaniline)	101-14-4
36.	Methyl methanesulfonate	66-27-3
121.	Naphthalene	91-20-3
122.	1,4-Naphthoquinone	130-15-4
123.	1-Naphthylamine	134-32-7
124.	2-Naphthylamine	91-59-8
125.	p-Nitroaniline	100-01-6
126.	Nitrobenzene	98-95-3
127.	4-Nitrophenol	100-02-7
128.	N-Nitrosodi-n-butylamine	924-16-3
129.	N-Nitrosodiethylamine	55-18-5
130.	N-Nitrosodimethylamine	62-75-9
131.	N-Nitrosomethylethylamine	10595-95-6
132.	N-Nitrosomorpholine	59-89-2
133.	N-Nitrosopiperidine	100-75-4
134.	N-Nitrosopyrrolidine	930-55-2
135.	5-Nitro-o-toluidine	99-65-8
136.	Pentachlorobenzene	608-93-5
137.	Pentachloroethane	76-01-7
138.	Pentachloronitrobenzene	82-68-8
139.	Pentachlorophenol	87-86-5
140.	Phenacetin	62-44-2
141.	Phenanthrene	85-01-8
142.	Phenol	108-95-2
220.	Phthalic anhydride	85-44-9
143.	2-Picoline	109-06-8
144.	Pronamide	23950-58-5
145.	Pyrene	129-00-0
146.	Resorcinol	108-46-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
147.	Safrole	94-59-7
148.	1,2,4,5-Tetrachlorobenzene	95-94-3
149.	2,3,4,6-Tetrachlorophenol	58-90-2
150.	1,2,4-Trichlorobenzene	120-82-1
151.	2,4,5-Trichlorophenol	95-95-4
152.	2,4,6-Trichlorophenol	88-06-2
153.	Tris(2,3-dibromopropyl) phosphate	126-72-7
	Metals	
154.	Antimony	7440-36-0
155.	Arsenic	7440-38-2
156.	Barium	7440-39-3
157.	Beryllium	7440-41-7
158.	Cadmium	7440-43-9
159.	Chromium (total)	7440-47-3
221.	Chromium (hexavalent)	-
160.	Copper	7440-50-8
161.	Lead	7439-92-1
162.	Mercury	7439-97-6
163.	Nickel	7440-02-0
164.	Selenium	7782-49-2
165.	Silver	7440-22-4
166.	Thallium	7440-28-0
167.	Vanadium	7440-62-2
168.	Zinc	7440-66-6
	Inorganics other than metals	
169.	Cyanide	57-12-5
170.	Fluoride	16964-48-8
171.	Sulfide	8496-25-8
	Organochlorine pesticides	
172.	Aldrin	309-00-2
173.	alpha-BHC	319-84-6
174.	beta-BHC	319-85-7
175.	delta-BHC	319-86-8

Table 1-1 (Continued)

BOAT reference no.	Constituent	CAS no.
	Organochlorine pesticides (continued)	
176.	gamma-BHC	58-89-9
177.	Chlordane	57-74-9
178.	DDD	72-54-8
179.	DDE	72-55-9
180.	DDT	50-29-3
181.	Dieldrin	60-57-1
182.	Endosulfan I	939-98-8
183.	Endosulfan II	33213-6-5
184.	Endrin	72-20-8
185.	Endrin aldehyde	7421-93-4
186.	Heptachlor	76-44-8
187.	Heptachlor epoxide	1024-57-3
188.	Isodrin	465-73-6
189.	Kepone	143-50-0
190.	Methoxyclor	72-43-5
191.	Toxaphene	8001-35-2
	Phenoxyacetic acid herbicides	
192.	2,4-Dichlorophenoxyacetic acid	94-75-7
193.	Silvex	93-72-1
194.	2,4,5-T	93-76-5
	Organophosphorous insecticides	
195.	Disulfoton	298-04-4
196.	Famphur	52-85-7
197.	Methyl parathion	298-00-0
198.	Parathion	56-38-2
199.	Phorate	298-02-2
	PCBs	
200.	Aroclor 1016	12674-11-2
201.	Aroclor 1221	11104-28-2
202.	Aroclor 1232	11141-16-5
203.	Aroclor 1242	53469-21-9
204.	Aroclor 1248	12672-29-6
205.	Aroclor 1254	11097-69-1
206.	Aroclor 1260	11096-82-5

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Dioxins and furans	
207.	Hexachlorodibenzo-p-dioxins	-
208.	Hexachlorodibenzofurans	-
209.	Pentachlorodibenzo-p-dioxins	-
210.	Pentachlorodibenzofurans	-
211.	Tetrachlorodibenzo-p-dioxins	-
212.	Tetrachlorodibenzofurans	-
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6

comprehensive list of hazardous constituents specifically regulated under RCRA. The BDAT list consists of those constituents that can be analyzed using methods published in SW-846, Third Edition.

The initial BDAT constituent list was published in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT") in March 1987. Additional constituents are added to the BDAT constituent list as more key constituents are identified for specific waste codes or as new analytical methods are developed for hazardous constituents. For example, since the list was published in March 1987, 18 additional constituents (hexavalent chromium, xylenes (all three isomers), benzal chloride, phthalic anhydride, ethylene oxide, acetone, n-butyl alcohol, 2-ethoxyethanol, ethyl acetate, ethyl benzene, ethyl ether, methanol, methyl isobutyl ketone, 2-nitropropane, 1,1,2-trichloro-1,2,2-trifluoroethane, and cyclohexanone) have been added to the list.

Chemicals are listed in Appendix VIII if they are shown in scientific studies to have toxic, carcinogenic, mutagenic, or teratogenic effects on humans or other life-forms, and they include such substances as those identified by the Agency's Carcinogen Assessment Group as being carcinogenic. A waste can be listed as a toxic waste on the basis that it contains a constituent in Appendix VIII.

Although Appendix VII, Appendix VIII, and the F003 and F005 ignitables provide a comprehensive list of RCRA-regulated hazardous constituents, not all of the constituents can be analyzed in a complex waste matrix. Therefore, constituents that could not be readily analyzed in an unknown waste matrix were not included on the initial BDAT constituent list. As mentioned above, however, the BDAT constituent list is a continuously growing list that does not preclude the addition of new constituents when analytical methods are developed.

There are five major reasons that constituents were not included on the BDAT constituent list:

1. Constituents are unstable. Based on their chemical structure, some constituents will either decompose in water or will ionize. For example, maleic anhydride will form maleic acid when it comes in contact with water, and copper cyanide will ionize to form copper and cyanide ions. However, EPA may choose to regulate the decomposition or ionization products.

2. EPA-approved or verified analytical methods are not available. Many constituents, such as 1,3,5-trinitrobenzene, are not measured adequately or even detected using any of EPA's analytical methods published in SW-846 Third Edition.

3. The constituent is a member of a chemical group designated in Appendix VIII as not otherwise specified (N.O.S.). Constituents listed as N.O.S., such as chlorinated phenols, are a generic group of some types of chemicals for which a single analytical procedure is not available. The individual members of each such group need to be listed to determine whether the constituents can be analyzed. For each N.O.S. group, all those constituents that can be readily analyzed are included in the BDAT constituent list.

4. Available analytical procedures are not appropriate for a complex waste matrix. Some compounds, such as auramine, can be analyzed as a pure constituent. However, in the presence of other constituents, the recommended analytical method does not positively identify the constituent. The use of high performance liquid chromatography (HPLC) presupposes a high expectation of finding the specific constituents of interest. In using this procedure to screen samples, protocols would have to be developed on a case-specific basis to verify the identity of constituents present in the samples. Therefore, HPLC is usually not an appropriate analytical procedure for complex samples containing unknown constituents.

5. Standards for analytical instrument calibration are not commercially available. For several constituents, such as benz(c)acridine, commercially available standards of a "reasonably" pure grade are not available. The unavailability of a standard was determined by a review of catalogs from specialty chemical manufacturers.

Two constituents (fluoride and sulfide) are not specifically included in Appendices VII and VIII; however, these compounds are included on the BDAT list as indicator constituents for compounds from Appendices VII and VIII such as hydrogen fluoride and hydrogen sulfide, which ionize in water.

The BDAT constituent list presented in Table 1-1 is divided into the following nine groups:

- Volatile organics;
- Semivolatile organics;
- Metals;
- Other inorganics;
- Organochlorine pesticides;
- Phenoxyacetic acid herbicides;
- Organophosphorous insecticides;
- PCBs; and
- Dioxins and furans.

The constituents were placed in these categories based on their chemical properties. The constituents in each group are expected to behave similarly during treatment and are also analyzed, with the exception of the metals and the other inorganics, by using the same analytical methods.

(2) Constituent selection analysis. The constituents that the Agency selects for regulation in each waste are, in general, those found in the untreated wastes at treatable concentrations. For certain waste

codes, the target list for the untreated waste may have been shortened (relative to analyses performed to test treatment technologies) because of the extreme unlikelihood that the constituent will be present.

In selecting constituents for regulation, the first step is to develop of list of potentially regulated constituents by summarizing all the constituents that are present or are likely to be present in the untreated waste at treatable concentrations. A constituent is considered present in a waste if the constituent (1) is detected in the untreated waste above the detection limit, (2) is detected in any of the treated residuals above the detection limit, or (3) is likely to be present based on the Agency's analyses of the waste-generating process. In case (2), the presence of other constituents in the untreated waste may interfere with the quantification of the constituent of concern, making the detection limit relatively high and resulting in a finding of "not detected" when, in fact, the constituent is present in the waste. Thus, the Agency reserves the right to regulate such constituents.

After developing a list of potential constituents for regulation. EPA reviews this list to determine if any of these constituents can be excluded from regulation because they would be controlled by regulation of other constituents on the list. This indicator analysis is done for two reasons: (1) it reduces the analytical cost burdens on the treater and (2) it facilitates implementation of the compliance and enforcement program. EPA's rationale for selection of regulated constituents for this waste code is presented in Section 6 of this background document.

(3) Calculation of standards. The final step in the calculation of the BDAT treatment standard is the multiplication of the average accuracy-corrected treatment value by a factor referred to by the Agency as the variability factor. This calculation takes into account that even well-designed and well-operated treatment systems will experience some fluctuations in performance. EPA expects that fluctuations will result from inherent mechanical limitations in treatment control systems, collection of treated samples, and analysis of these samples. All of the above fluctuations can be expected to occur at well-designed and well-operated treatment facilities. Therefore, setting treatment standards utilizing a variability factor should be viewed not as a relaxing of section 3004(m) requirements, but rather as a function of the normal variability of the treatment processes. A treatment facility will have to be designed to meet the mean achievable treatment performance level to ensure that the performance levels remain within the limits of the treatment standard.

The Agency calculates a variability factor for each constituent of concern within a waste treatability group using the statistical calculation presented in Appendix A. The equation for calculating the variability factor is the same as that used by EPA for the development of numerous regulations in the Effluent Guidelines Program under the Clean Water Act. The variability factor establishes the instantaneous maximum based on the 99th percentile value.

There is an additional step in the calculation of the treatment standards in those instances where the ANOVA analysis shows that more than one technology achieves a level of performance that represents BDAT. In such instances, the BDAT treatment standard for each constituent of concern is calculated by first averaging the mean performance value for each technology and then multiplying that value by the highest variability factor among the technologies considered. This procedure ensures that all the technologies used as the basis for the BDAT treatment standards will achieve full compliance.

1.2.5 Compliance with Performance Standards

Usually the treatment standards reflect performance achieved by the best demonstrated available technology (BDAT). As such, compliance with these numerical standards requires only that the treatment level be achieved prior to land disposal. It does not require the use of any particular treatment technology. While dilution of the waste as a means to comply with the standards is prohibited, wastes that are generated in such a way as to naturally meet the standards can be land disposed without treatment. With the exception of treatment standards that prohibit land disposal or that specify use of certain treatment methods, all established treatment standards are expressed as concentration levels.

EPA is using both the total constituent concentration and the concentration of the constituent in the TCLP extract of the treated waste as a measure of technology performance.

For all organic constituents, EPA is basing the treatment standards on the total constituent concentration found in the treated waste. EPA is using this measurement because most technologies for treatment of organics destroy or remove organics compounds. Accordingly, the best measure of performance would be the total amount of constituent remaining after treatment. (NOTE: EPA's land disposal restrictions for solvent waste codes F001-F005 (51 FR 40572) use the TCLP extract value as a measure of performance. At the time that EPA promulgated the treatment standards for F001-F005, useful data were not available on total constituent concentrations in treated residuals, and, as a result, the TCLP data were considered to be the best measure of performance.)

For all metal constituents, EPA is using both total constituent concentration and/or the TCLP extract concentration as the basis for treatment standards. The total constituent concentration is being used when the technology basis includes a metal recovery operation. The underlying principle of metal recovery is that it reduces the amount of metal in a waste by separating the metal for recovery; total constituent concentration in the treated residual, therefore, is an important measure of performance for this technology. Additionally, EPA also believes that it is important that any remaining metal in a treated residual waste not be in a state that is easily leachable; accordingly, EPA is also using the TCLP extract concentration as a measure of performance. It is important to note that for wastes for which treatment standards are based on a metal recovery process, the facility has to comply with both the total and the TCLP extract constituent concentrations prior to land disposing the waste.

In cases where treatment standards for metals are not based on recovery techniques but rather on stabilization, EPA is using only the TCLP value as a measure of performance. The Agency's rationale is that stabilization is not meant to reduce the concentration of metal in a waste but only to chemically minimize the ability of the metal to leach.

1.2.6 Identification of BDAT

BDAT for a waste must be the "best" of the demonstrated available technologies. EPA determines which technology constitutes "best" after screening the available data from each demonstrated technology, adjusting these data for accuracy, and comparing the performance of each demonstrated technology to that of the others. If only one technology is identified as demonstrated, it is considered "best"; if it is available, the technology is BDAT.

(1) Screening of treatment data. The first activity in determining which of the treatment technologies represent treatment by BDAT is to screen the treatment performance data from each of the demonstrated and available technologies according to the following criteria:

1. Design and operating data associated with the treatment data must reflect a well-designed, well-operated system for each treatment data point. (The specific design and operating parameters for each demonstrated technology for the waste code(s) of interest are discussed in Section 3.2 of this document.)

2. Sufficient QA/QC data must be available to determine the true values of the data from the treated waste. This screening criterion involves adjustment of treated data to take into account that the true value may be different from the measured value. This discrepancy generally is caused by other constituents in the waste that can mask results or otherwise interfere with the analysis of the constituent of concern.

3. The measure of performance must be consistent with EPA's approach to evaluating treatment by type of constituents (e.g., total concentration data for organics, and total concentration and TCLP extract concentration for metals from the residual).

In the absence of data needed to perform the screening analysis, EPA will make decisions on a case-by-case basis as to whether to use the data as a basis for the treatment standards. The factors included in this case-by-case analysis will be the actual treatment levels achieved, the availability of the treatment data and their completeness (with respect to the above criteria), and EPA's assessment of whether the untreated waste represents the waste code of concern.

(2) Comparison of treatment data. In cases in which EPA has treatment data from more than one demonstrated available technology following the screening activity, EPA uses the statistical method known as analysis of variance (ANOVA) to determine if one technology performs significantly better than the others. This statistical method (summarized in Appendix A) provides a measure of the differences between two data sets. Specifically, EPA uses the analysis of variance to determine whether BDAT represents a level of performance achieved by only one technology or represents a level of performance achieved by more than one (or all) of the technologies. If EPA finds that one technology performs significantly better (i.e., is "best"), BDAT treatment standards

are the level of performance achieved by that best technology multiplied by the corresponding variability factor for each regulated constituent. If the Agency finds that the levels of performance for one or more technologies are not statistically different, EPA averages the performance values achieved by each technology and then multiplies this value by the largest variability factor associated with any of the technologies.

(3) Quality assurance/quality control. This section presents the principal quality assurance/quality control (QA/QC) procedures employed in screening and adjusting the data to be used in the calculation of treatment standards. Additional QA/QC procedures used in collecting and screening data for the BDAT program are presented in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011.

To calculate the treatment standards for the land disposal restriction rules, it is first necessary to determine the recovery value for each constituent (the amount of constituent recovered after spiking--which is the addition of a known amount of the constituent--minus the initial concentration in the samples, all divided by the spike amount added) for each spiked sample of the treated residual. Once the recovery values are determined, the following procedures are used to select the appropriate percent recovery value to adjust the analytical data:

1. If duplicate spike recovery values are available for the constituent of interest, the data are adjusted by the lowest available percent recovery value (i.e., the value that will yield the most conservative estimate of treatment achieved). However, if a spike recovery value of less than 20 percent is reported for a specific constituent, the data are not used to set treatment standards because the Agency does not have sufficient confidence in the reported value to set a national standard.

2. If data are not available for a specific constituent but are available for an isomer, then the spike recovery data are transferred from the isomer and the data are adjusted using the percent recovery selected according to the procedure described in (1) above.

3. If data are not available for a specific constituent but are available for a similar class of constituents (e.g., volatile organics, acid-extractable semivolatiles), then spike recovery data available for this class of constituents are transferred. All spike recovery values greater than or equal to 20 percent for a spike sample are averaged and the constituent concentration is adjusted by the average recovery value. If spiked recovery data are available for more than one sample, the average is calculated for each sample and the data are adjusted by using the lowest average value.

4. If matrix spike recovery data are not available for a set of data to be used to calculate treatment standards, then matrix spike recovery data are transferred from a waste that the Agency believes is similar (e.g., if the data represent an ash from incineration, then data from other incinerator ashes could be used). While EPA recognizes that transfer of matrix spike recovery data from a similar waste is not an exact analysis, this is considered the best approach for adjusting the data to account for the fact that most analyses do not result in extraction of 100 percent of the constituent. In assessing the recovery data to be transferred, the procedures outlined in (1), (2), and (3) above are followed.

The analytical procedures employed to generate the data used to calculate the treatment standards are listed in Appendix B of this document. In cases where alternatives or equivalent procedures and/or equipment are allowed in EPA's SW-846, Third Edition methods, the specific procedures and equipment used are documented. In addition, any deviations from the SW-846, Third Edition methods used to analyze the specific waste matrices are documented. It is important to note that the Agency will use the methods and procedures delineated in Appendix B to enforce the treatment standards presented in Section 7 of this document. Accordingly, facilities should use these procedures in assessing the performance of their treatment systems.

1.2.7 BDAT Treatment Standards for "Derived-From" and "Mixed" Wastes

(1) Wastes from treatment trains generating multiple residues. In a number of instances, the proposed BDAT consists of a series of operations, each of which generates a waste residue. For example, the proposed BDAT for a certain waste code is based on solvent extraction, steam stripping, and activated carbon adsorption. Each of these treatment steps generates a waste requiring treatment--a solvent-containing stream from solvent extraction, a stripper overhead, and spent activated carbon. Treatment of these wastes may generate further residues; for instance, spent activated carbon (if not regenerated) could be incinerated, generating an ash and possibly a scrubber water waste. Ultimately, additional wastes are generated that may require land disposal. With respect to these wastes, the Agency wishes to emphasize the following points:

1. All of the residues from treating the original listed wastes are likewise considered to be the listed waste by virtue of the derived-from rule contained in 40 CFR 261.3(c)(2). (This point is discussed more fully in (2) below.) Consequently, all of the wastes generated in the course of treatment would be prohibited from land disposal unless they satisfy the treatment standard or meet one of the exceptions to the prohibition.

2. The Agency's proposed treatment standards generally contain a concentration level for wastewaters and a concentration level for nonwastewaters. The treatment standards apply to all of the wastes generated in treating the original prohibited waste. Thus, all derived-from wastes meeting the Agency definition of wastewater (less than 1 percent total organic carbon (TOC) and less than 1 percent total suspended solids) would have to meet the treatment standard for wastewaters. All residuals not meeting this definition would have to meet the treatment standard for nonwastewaters. EPA wishes to make clear that this approach is not meant to allow partial treatment in order to comply with the applicable standard.

3. The Agency has not performed tests, in all cases, on every waste that can result from every part of the treatment train. However, the Agency's treatment standards are based on treatment of the most concentrated form of the waste. Consequently, the Agency believes that the less concentrated wastes generated in the course of treatment will also be able to be treated to meet this value.

(2) Mixtures and other derived-from residues. There is a further question as to the applicability of the BDAT treatment standards to residues generated not from treating the waste (as discussed above), but from other types of management. Examples are contaminated soil or leachate that is derived from managing the waste. In these cases, the mixture is still deemed to be the listed waste, either because of the derived-from rule (40 CFR 261.3(c)(2)(i)) or the mixture rule (40 CFR 261.3(a)(2)(iii) and (iv)) or because the listed waste is contained in the matrix (see, for example, 40 CFR 261.33(d)). The prohibition for the particular listed waste consequently applies to this type of waste.

The Agency believes that the majority of these types of residues can meet the treatment standards for the underlying listed wastes (with the possible exception of contaminated soil and debris for which the Agency is currently investigating whether it is appropriate to establish a separate treatability subcategorization). For the most part, these residues will be less concentrated than the original listed waste. The Agency's treatment standards also make a generous allowance for process variability by assuming that all treatability values used to establish the standard are lognormally distributed. The waste also might be amenable to a relatively nonvariable form of treatment technology such as incineration. Finally, and perhaps most important, the rules contain a treatability variance that allows a petitioner to demonstrate that its waste cannot be treated to the level specified in the rule (40 CFR Part 268.44(a)). This provision provides a safety valve that allows persons with unusual waste matrices to demonstrate the appropriateness of a different standard. The Agency, to date, has not received any petitions under this provision (for example, for residues contaminated with a prohibited solvent waste), indicating, in the Agency's view, that the existing standards are generally achievable.

(3) Residues from managing listed wastes or that contain listed wastes. The Agency has been asked if and when residues from managing hazardous wastes, such as leachate and contaminated ground water, become subject to the land disposal prohibitions. Although the Agency believes this question to be settled by existing rules and interpretative statements, to avoid any possible confusion the Agency will address the question again.

Residues from managing First Third wastes, listed California List wastes, and spent solvent and dioxin wastes are all considered to be subject to the prohibitions for the listed hazardous waste as originally generated. Residues from managing California List wastes likewise are subject to the California List prohibitions when the residues themselves exhibit a characteristic of hazardous waste. This determination stems directly from the derived-from rule in 40 CFR 261.3(c)(2) or, in some cases, from the fact that the waste is mixed with or otherwise contains the listed waste. The underlying principle stated in all of these provisions is that listed wastes remain listed until delisted.

The Agency's historic practice in processing delisting petitions that address mixing residuals has been to consider them to be the listed waste and to require that delisting petitioners address all constituents for which the derived-from waste (or other mixed waste) was listed. The language in 40 CFR 260.22(b) states that mixtures or derived-from residues can be delisted provided a delisting petitioner makes a demonstration identical to that which a delisting petitioner would make for the original listed waste. Consequently, these residues are treated as the original listed waste for delisting purposes. The statute likewise takes this position, indicating that soil and debris that are contaminated with listed spent solvents or dioxin wastes are subject to the prohibition for these wastes even though these wastes are not the originally generated waste, but rather are a residual from management (RCRA section 3004(e)(3)). It is EPA's view that all such residues are covered by the existing prohibitions and treatment standards for the listed hazardous waste that these residues contain or from which they are derived.

1.2.8 Transfer of Treatment Standards

EPA is proposing some treatment standards that are not based on testing of the treatment technology on the specific waste subject to the treatment standard. The Agency has determined that the constituents present in the untested waste can be treated to the same performance levels as those observed in other wastes for which EPA has previously developed treatment data. EPA believes that transferring treatment performance data for use in establishing treatment standards for untested wastes is technically valid in cases where the untested wastes are generated from similar industries or processing steps, or have similar waste characteristics affecting performance and treatment selection. Transfer of treatment standards to similar wastes or wastes from similar processing steps requires little formal analysis. However, in a case where only the industry is similar, EPA more closely examines the waste characteristics prior to deciding whether the untested waste constituents can be treated to levels associated with tested wastes.

EPA undertakes a two-step analysis when determining whether constituents in the untested wastes can be treated to the same level of performance as in the tested waste. First, EPA reviews the available waste characterization data to identify those parameters that are expected to affect treatment selection. EPA has identified some of the most important constituents and other parameters needed to select the treatment technology appropriate for the given waste(s) in Section 3.

Second, when analysis suggests that an untested waste can be treated with the same technology as a waste for which treatment performance data are already available, EPA analyzes a more detailed list of characteristics that the Agency believes will affect the performance of the technology. By examining and comparing these characteristics, the Agency determines whether the untested wastes will achieve the same level of treatment as the tested waste. Where the Agency determines that the untested waste can be treated as well or better than the tested waste, the treatment standards can be transferred.

1.3 Variance from the BDAT Treatment Standard

The Agency recognizes that there may exist unique wastes that cannot be treated to the level specified as the treatment standard. In such a case, a generator or owner/operator may submit a petition to the Administrator requesting a variance from the treatment standard. A particular waste may be significantly different from the wastes on which the treatment standards are based because the subject waste contains a more complex matrix that makes it more difficult to treat. For example, complex mixtures may be formed when a restricted waste is mixed with other waste streams by spills or other forms of inadvertent mixing. As a result, the treatability of the restricted waste may be altered such that it cannot meet the applicable treatment standard.

Variance petitions must demonstrate that the treatment standard established for a given waste cannot be met. This demonstration can be made by showing that attempts to treat the waste by available technologies were not successful or by performing appropriate analyses of the waste, including waste characteristics affecting performance, which demonstrate that the waste cannot be treated to the specified levels. Variances will not be granted based solely on a showing that adequate BDAT treatment capacity is unavailable. (Such demonstrations can be made according to the provisions in Part 268.5 of RCRA for case-by-case extensions of the effective date.) The Agency will consider granting generic petitions provided that representative data are submitted to support a variance for each facility covered by the petition.

Petitioners should submit at least one copy to:

The Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

An additional copy marked "Treatability Variance" should be submitted to:

Chief, Waste Treatment Branch
Office of Solid Waste (WH-565)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Petitions containing confidential information should be sent with only the inner envelope marked "Treatability Variance" and "Confidential Business Information" and with the contents marked in accordance with the

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The petition should contain the following information:

1. The petitioner's name and address.
2. A statement of the petitioner's interest in the proposed action.
3. The name, address, and EPA identification number of the facility generating the waste, and the name and telephone number of the plant contact.
4. The process(es) and feed materials generating the waste and an assessment of whether such process(es) or feed materials may produce a waste that is not covered by the demonstration.
5. A description of the waste sufficient for comparison with the waste considered by the Agency in developing BDAT, and an estimate of the average and maximum monthly and annual quantities of waste covered by the demonstration. (Note: The petitioner should consult the appropriate BDAT background document for determining the characteristics of the wastes considered in developing treatment standards.)
6. If the waste has been treated, a description of the system used for treating the waste, including the process design and operating conditions. The petition should include the reasons the treatment standards are not achievable and/or why the petitioner believes the standards are based on inappropriate technology for treating the waste. (Note: The petitioner should refer to the BDAT background document as guidance for determining the design and operating parameters that the Agency used in developing treatment standards.)
7. A description of the alternative treatment systems examined by the petitioner (if any); a description of the treatment system deemed appropriate by the petitioner for the waste in question; and, as appropriate, the concentrations in the treatment residual or extract of the treatment residual (i.e., using the TCLP, where appropriate, for stabilized metals) that can be achieved by applying such treatment to the waste.
8. A description of those parameters affecting treatment selection and waste characteristics that affect performance, including results of all analyses. (See Section 3 for a discussion of

waste characteristics affecting performance that the Agency has identified for the technology representing BDAT.)

9. The dates of the sampling and testing.

10. A description of the methodologies and equipment used to obtain representative samples.

11. A description of the sample handling and preparation techniques, including techniques used for extraction, containerization, and preservation of the samples.

12. A description of analytical procedures used, including QA/QC methods.

After receiving a petition for a variance, the Administrator may request any additional information or waste samples that may be required to evaluate and process the petition. Additionally, all petitioners must certify that the information provided to the Agency is accurate under 40 CFR 268.4(b).

In determining whether a variance will be granted, the Agency will first look at the design and operation of the treatment system being used. If EPA determines that the technology and operation are consistent with BDAT, the Agency will evaluate the waste to determine if the waste matrix and/or physical parameters are such that the BDAT treatment standards reflect treatment of this waste. Essentially, this latter analysis will concern the parameters affecting treatment selection and waste characteristics affecting performance parameters.

In cases where BDAT is based on more than one technology, the petitioner will need to demonstrate that the treatment standard cannot be met using any of the technologies, or that none of the technologies are appropriate for treatment of the waste. After the Agency has made a determination on the petition, the Agency's findings will be published in the Federal Register, followed by a 30-day period for public comment. After review of the public comments, EPA will publish its final determination in the Federal Register as an amendment to the treatment standards in 40 CFR Part 268, Subpart D.

2. INDUSTRIES AFFECTED AND WASTE CHARACTERIZATION

This section discusses the industries that generate K024, describes the process that generates the waste, and presents waste characterization data.

2.1 Industry Affected and Process Description

The listed waste K024 is generated in a distillation column as bottom residues during the production of phthalic anhydride from napthalene in the organic chemical industry. The Agency estimates that only one facility uses this process and generates K024 waste. This facility is located in the State of Illinois (EPA Region V) and generates a maximum of 600 tons of K024 waste per year.

Phthalic anhydride is manufactured by a process that uses a vaporized napthalene and air mixture fed into a fixed-bed reactor with a vanadium pentoxide catalyst. The naphthalene is oxidized to phthalic anhydride, carbon dioxide, and water at a temperature of about 350°C. These gases pass through a vapor cooler that reduces the gas temperature just below the dew point (approximately 126°C). The condensed liquid is then routed into crude phthalic anhydride storage.

The crude phthalic anhydride is subsequently heated at atmospheric pressure to dehydrate traces of phthalic acid and to convert other compounds to high boiling compounds that can be separated from the product during distillation. Other chemicals are added to promote condensation reactions and to shorten the time required for purification. These chemicals include sodium carbonate, sodium hydroxide, or a material to tie up naphthoquinone in a polymer state so that it will be easily removed from the product. The bottoms or heavy ends from the distillation column constitute the waste stream K024. Figure 2-1 is a process schematic of the manufacture of phthalic anhydride and the generation of the listed waste K024. K024 from the distillation column is directly drummed at a temperature of 250°C and then allowed to cool prior to disposal.

2.2 Waste Characterization

All waste characterization data available to the Agency for K024 waste are presented below. The major constituents in the waste and their approximate concentrations are presented in Table 2-1. The percent concentration of each major constituent in the waste was determined from best estimates based on chemical analyses and discussion with the generator. Less than 6 percent of the waste is composed of BDAT constituents (for BDAT constituent list, refer to Section 1.2.4), of which 5 percent is phthalic anhydride. (Analytical results upon which the estimate is based are reported in the Onsite Engineering Report for K024.) The BDAT constituent composition and other data are presented in Table 2-2. No BDAT constituents of interest, except phthalic anhydride, were detected at significant concentrations in the untreated waste sample.

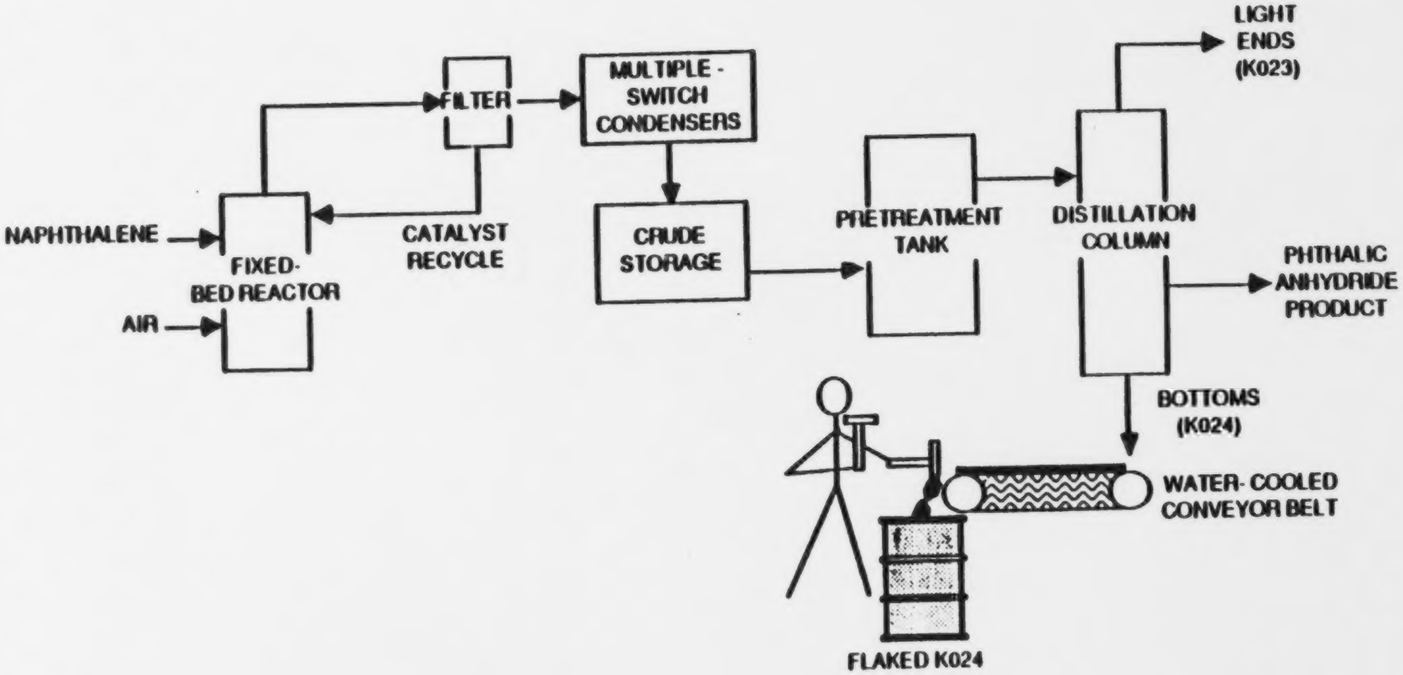

NAPHTHALENE
AIR
FIXED-BED REACTOR
CATALYST RECYCLE
FILTER
MULTIPLE-SWITCH CONDENSERS
CRUDE STORAGE
PRETREATMENT TANK
DISTILLATION COLUMN
LIGHT ENDS (K023)
PHTHALIC ANHYDRIDE PRODUCT
BOTTOMS (K024)
WATER-COOLED CONVEYOR BELT
FLAKED K024

Figure 2-1 Schematic Diagram of the Generation of K024 and Preparation of K024 for Test Burns

Table 2-1 Major Constituent Composition for Untreated K024 Waste

Major constituents	Concentration (%)
Phthalic anhydride[a]	5
Ash	10
Water	<1
Other BDAT constituents	<1
Polymer material[b]	83
TOTAL	100

[a] This is the product that remains in the waste.

[b] Reported by Koppers to be produced from reactions of sodium carbonate, 1,4-naphthaquinone, and other organic and inorganic impurities from process feed materials.

Reference: USEPA 1987b.

Table 2-2 BDAT Constituent Composition and Other Data

Constituent		CAS no.	Untreated waste concentration (ppm)
Volatile organics			
15.[a]	Chloromethane	74-87-3	<10-40
17.	1,2-Dibromo-3-chloropropane	96-12-8	<10
21.	Dichlorodifluoro-methane	75-71-8	<10
34.	Methyl ethyl ketone	78-93-3	200-700
Semivolatile organics			
220.[b]	Phthalic acid[c,d]	85-44-9	13,000-220,000
	9,10-Anthracenedione[c]	84-65-1	5,400-6,700
Metals			
155.	Arsenic	7440-36-0	No metal analyses were performed
156.	Barium	7440-39-3	
158.	Cadmium	7440-43-9	
159.	Chromium	7440-47-3	
160.	Copper	7440-50-8	
161.	Lead	7439-92-1	
163.	Nickel	7440-02-0	
168.	Zinc	7440-66-6	
Other parameters			
	Btu Content (Btu/lb)		10,000-20,000
	Ash %		5-10
	Water %		<1
	Volatile matter (dry basis) %	65.42	
	Sulfur %		1.61
	Carbon %		71.55

[a] BDAT constituent number.

[b] This BDAT constituent number is given to phthalic anhydride.

[c] Non-BDAT constituent.

[d] Phthalic acid is chosen as a surrogate constituent for phthalic anhydride. Phthalic anhydride is not detectable or measureable because it is hydrolyzed to phthalic acid during analysis and therefore the presence of phthalic anhydride in the waste can be detected only in the form of phthalic acid.

Reference: USEPA 1987b, Section 2.1.2 and Tables 2-1 and 6-1 to 6-6.

3. APPLICABLE/DEMONSTRATED TREATMENT TECHNOLOGIES

This section identifies the applicable and demonstrated treatment technology for K024 waste. A detailed discussion is provided for the technology that is demonstrated.

3.1 Applicable Treatment Technology

As shown in Section 2.3, K024 waste contains BDAT list organic constituents. The Agency has identified incineration as the applicable destruction technology because this technology is applicable for organic wastes such as K024, with high Btu content, high solids, low untreatable metals concentrations, and low water content. This selection is based on information in literature, information obtained from engineering site visits, and information submitted by industry. No other applicable technologies were identified.

3.2 Demonstrated Treatment Technology

Currently, the sole generator of K024 does not treat the waste generated during the production of phthalic anhydride from naphthalene but disposes of it as a drummed waste. The Agency cannot identify any facilities that currently use incinerators to treat K024 waste. However, incineration is demonstrated on wastes that are similar to K024 (high BTU content and organic solids) and therefore the Agency believes that incineration is demonstrated on K024 waste.

3.2.1 Incineration

This section addresses the commonly used incineration technologies: liquid injection, rotary kiln, fluidized bed, and fixed hearth. A discussion is provided regarding the applicability of these technologies, the underlying principles of operation, a technology description, waste characteristics that affect performance, and, finally, important design and operating parameters. As appropriate, the subsections are divided by type of incineration unit.

(1) Applicability and use of incineration.

(a) Liquid injection. Liquid injection is applicable to wastes that have viscosity values low enough that the waste can be atomized in the combustion chamber. A range of literature maximum viscosity values are reported with the low being 100 SSU and the high being 10,000 SSU. It is important to note that viscosity is temperature dependent so that while liquid injection may not be applicable to a waste at ambient conditions, it may be applicable when the waste is heated. Other factors that affect the use of liquid injection are particle size and the presence of suspended solids. Both of these waste parameters can cause plugging of the burner nozzle.

(b) Rotary kiln/fluidized bed/fixed hearth. These incineration technologies are applicable to a wide range of hazardous wastes. They can be used on wastes that contain high or low total organic content, high or low filterable solids, various viscosity ranges, and a range of other waste parameters. EPA has not found these technologies to be demonstrated on wastes that are composed essentially of metals with low organic concentrations. In addition, the Agency expects that some of the high metal content wastes may not be compatible with existing and future air emission limits without emission controls far more extensive than those currently used.

(2) Underlying principles of operation.

(a) Liquid injection. The basic operating principle of this incineration technology is that incoming liquid wastes are volatilized and then additional heat is supplied to the waste to destabilize the chemical bonds. Once the chemical bonds are broken, these constituents react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the bonds is referred to as the energy of activation.

(b) Rotary kiln and fixed hearth. There are two distinct principles of operation for these incineration technologies, one for each of the chambers involved. In the primary chamber, energy, in the form of heat, is transferred to the waste to achieve volatilization of the various organic waste constituents. During this volatilization process some of the organic constituents will oxidize to carbon dioxide and water vapor. In the secondary chamber, additional heat is supplied to overcome the energy requirements needed to destabilize the chemical bonds and allow the constituents to react with excess oxygen to form carbon dioxide and water vapor. The principle of operation for the secondary chamber is similar to that of liquid injection.

(c) Fluidized bed. The principle of operation for this incineration technology is somewhat different than that for rotary kiln and fixed hearth incineration relative to the functions of the primary and secondary chambers. In fluidized bed incineration, the purpose of the primary chamber is not only to volatilize the wastes but also to essentially combust the waste. Destruction of the waste organics can be accomplished to a better degree in the primary chamber of a fluidized bed incinerator than in that of a rotary kiln or fixed hearth incinerator because of (1) improved heat transfer from fluidization of the waste using forced air and (2) the fact that the fluidization process provides sufficient oxygen and turbulence to convert the organics to carbon dioxide and water vapor. The secondary chamber (referred to as the freeboard) generally does not have an afterburner; however, additional time is provided for conversion of the organic constituents to carbon dioxide, water vapor, and hydrochloric acid if chlorine is present in the waste.

(3) Description of the incineration process.

(a) Liquid injection. The liquid injection system is capable of incinerating a wide range of gases and liquids. The combustion system has a simple design with virtually no moving parts. A burner or nozzle atomizes the liquid waste and injects it into the combustion chamber, where it burns in the presence of air or oxygen. A forced draft system supplies the combustion chamber with air to provide oxygen for combustion and turbulence for mixing. The combustion chamber is usually a cyclinder lined with refractory (i.e., heat-resistant) brick and can be fired horizontally, vertically upward, or vertically downward. Figure 3-1 illustrates a liquid injection incineration system.

(b) Rotary kiln. A rotary kiln is a slowly rotating, refractory-lined cyclinder that is mounted at a slight incline from the

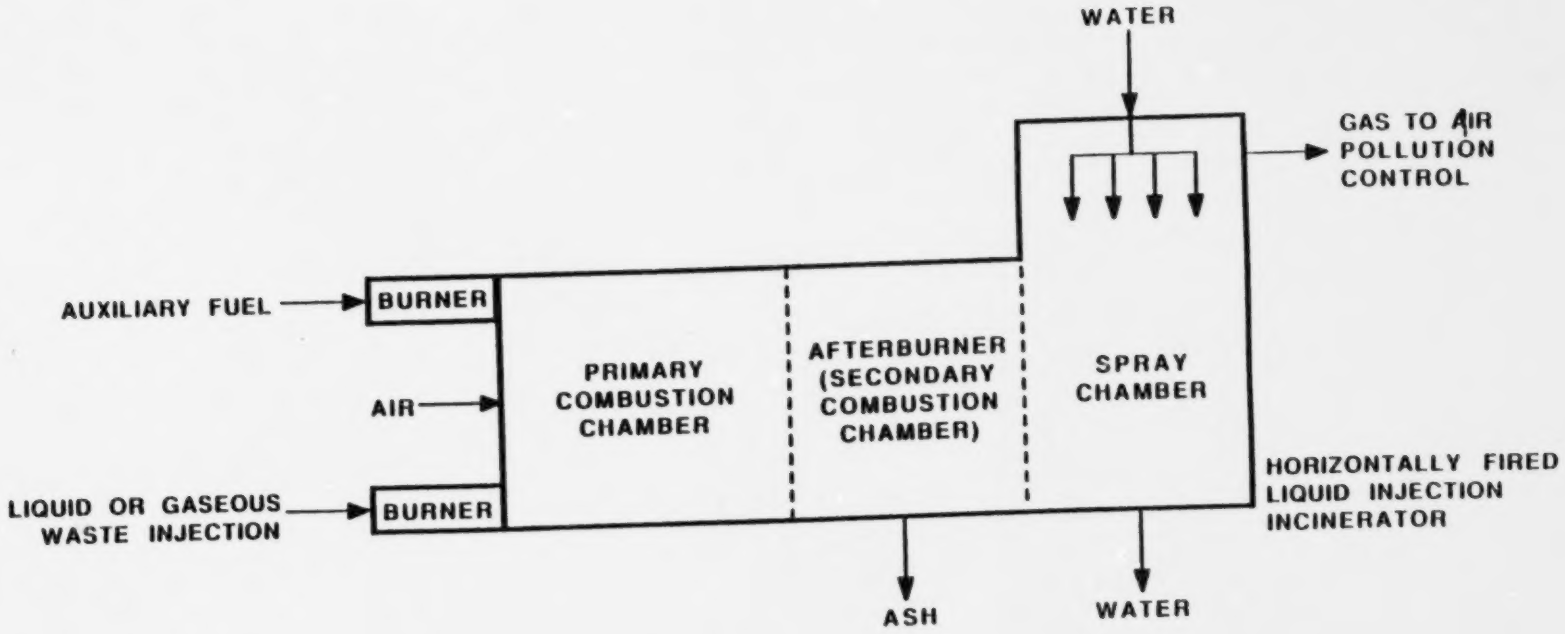

WATER
GAS TO AIR POLLUTION CONTROL
AUXILIARY FUEL
BURNER
AIR
LIQUID OR GASEOUS WASTE INJECTION
BURNER
PRIMARY COMBUSTION CHAMBER
AFTERBURNER (SECONDARY COMBUSTION CHAMBER)
SPRAY CHAMBER
HORIZONTALLY FIRED LIQUID INJECTION INCINERATOR
ASH
WATER

FIGURE 3-1
LIQUID INJECTION INCINERATOR

horizontal (see Figure 3-2). Solid wastes enter at the high end of the kiln, and liquid or gaseous wastes enter through atomizing nozzles in the kiln or afterburner section. Rotation of the kiln exposes the solids to the heat, vaporizes them, and allows them to combust by mixing with air. The rotation also causes the ash to move to the lower end of the kiln, where it can be removed. Rotary kiln systems usually have a secondary combustion chamber or afterburner following the kiln for further combustion of the volatilized components of solid wastes.

(c) Fluidized bed. A fluidized bed incinerator consists of a column containing inert particles such as sand, which is referred to as the bed. Air, driven by a blower, enters the bottom of the bed to fluidize the sand. Air passage through the bed promotes rapid and uniform mixing of the injected waste material within the fluidized bed. The fluidized bed has an extremely high heat capacity (approximately three times that of flue gas at the same temperature), thereby providing a large heat reservoir. The injected waste reaches ignition temperature quickly and transfers the heat of combustion back to the bed. Continued bed agitation by the fluidizing air allows larger particles to remain suspended in the combustion zone (see Figure 3-3).

(d) Fixed hearth incineration. Fixed hearth incineration, also called controlled air or starved air incineration, is another major technology used for hazardous waste incineration. Fixed hearth incineration is a two-stage combustion process (see Figure 3-4). Waste is ram-fed into the first stage, or primary chamber, and burned at less

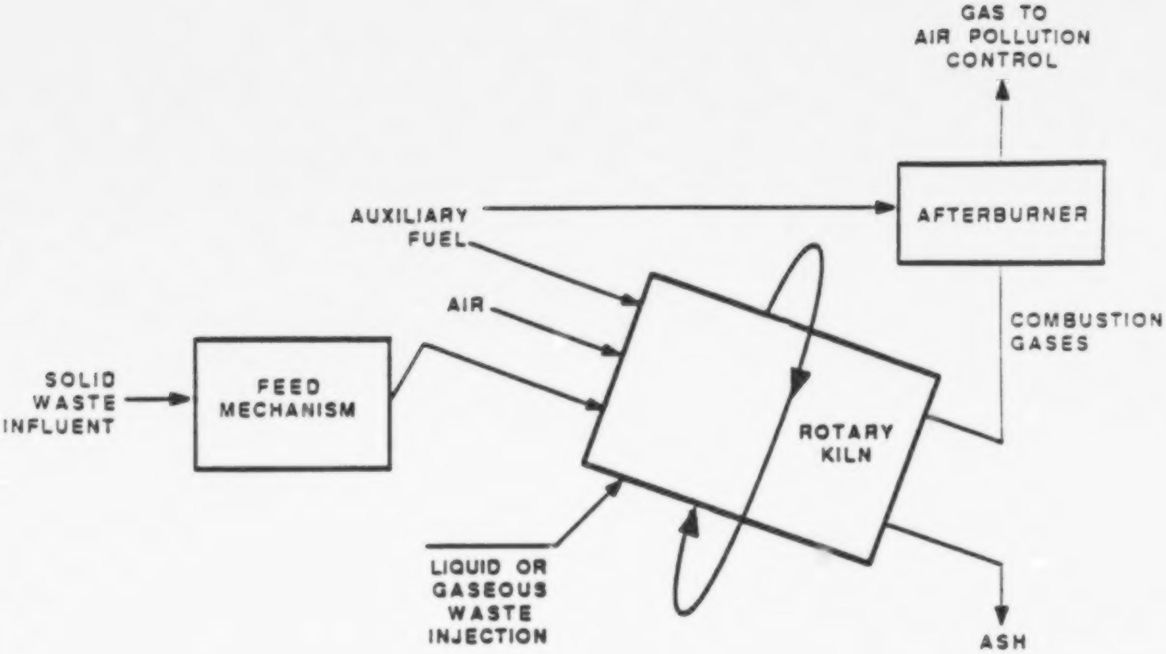

GAS TO
AIR POLLUTION
CONTROL
AFTERBURNER
AUXILIARY
FUEL
COMBUSTION
GASES
AIR
SOLID
WASTE
INFLUENT
FEED
MECHANISM
ROTARY
KILN
LIQUID OR
GASEOUS
WASTE
INJECTION
ASH

FIGURE 3-2
ROTARY KILN INCINERATOR

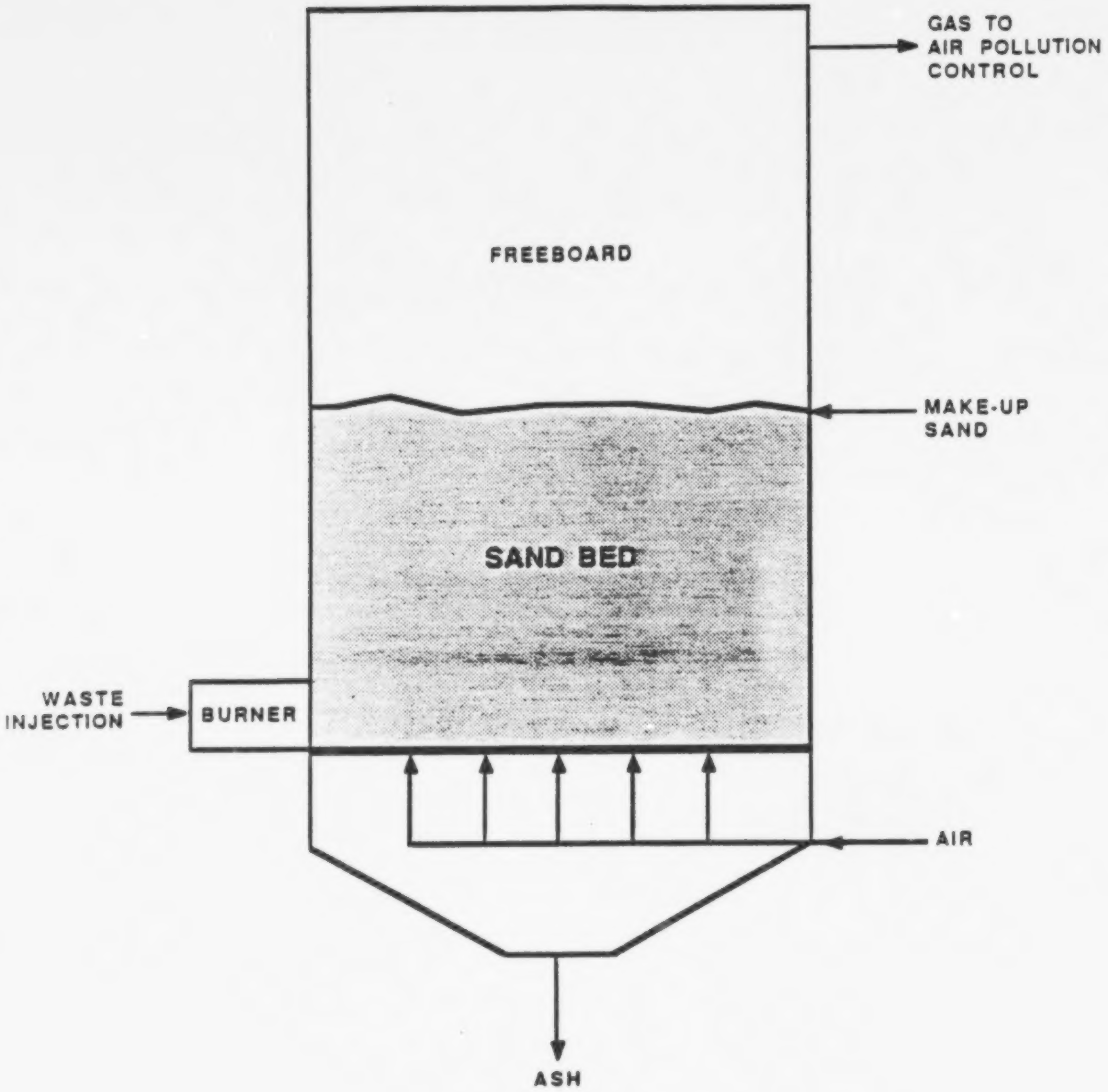

GAS TO
AIR POLLUTION
CONTROL
FREEBOARD
MAKE-UP
SAND
SAND BED
WASTE
INJECTION
BURNER
AIR
ASH

FIGURE 3-3
FLUIDIZED BED INCINERATOR

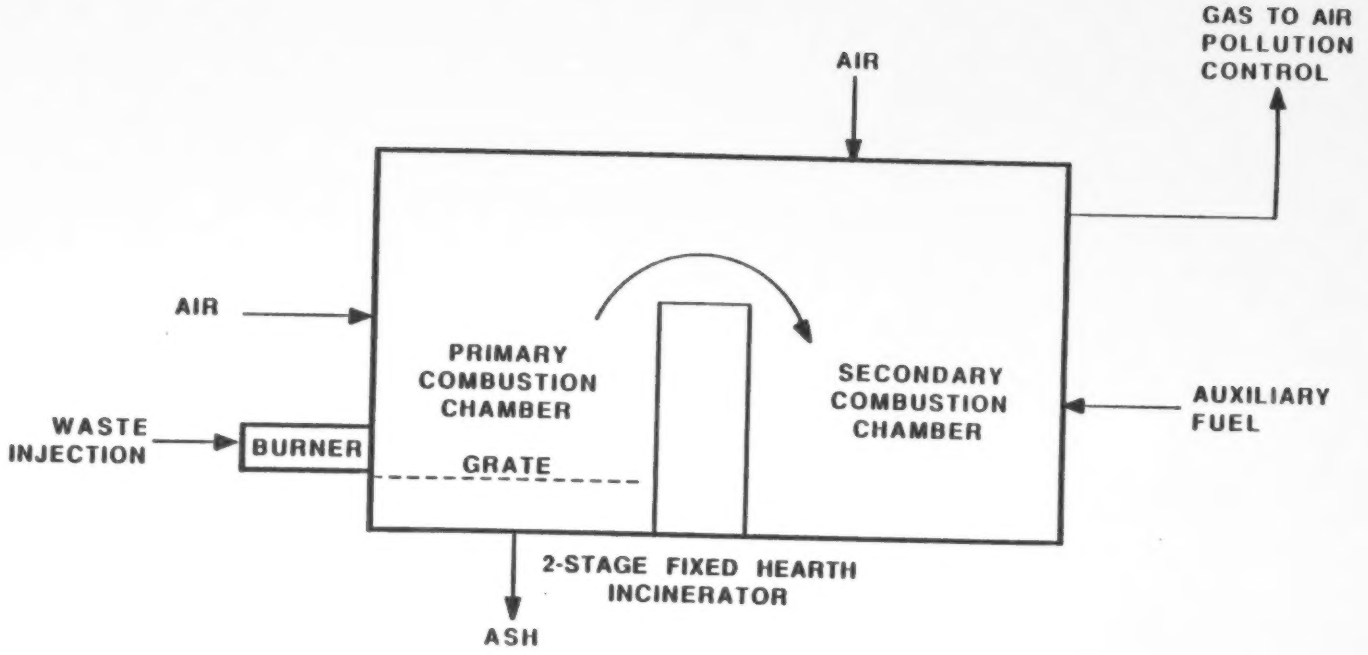

GAS TO AIR POLLUTION CONTROL
AIR
AIR
PRIMARY COMBUSTION CHAMBER
SECONDARY COMBUSTION CHAMBER
AUXILIARY FUEL
WASTE INJECTION
BURNER
GRATE
2-STAGE FIXED HEARTH INCINERATOR
ASH

FIGURE 3-4
FIXED HEARTH INCINERATOR

than stoichiometric conditions. The resultant smoke and pyrolysis products, consisting primarily of volatile hydrocarbons and carbon monoxide, along with the normal products of combustion, pass to the secondary chamber. Here, additional air is injected to complete the combustion. This two-stage process generally yields low stack particulate and carbon monoxide (CO) emissions. The primary chamber combustion reactions and combustion gas are maintained at low levels by the starved air conditions so that particulate entrainment and carryover are minimized.

(e) Air pollution controls. Following incineration of hazardous wastes, combustion gases are generally further treated in an air pollution control system. The presence of chlorine or other halogens in the waste requires a scrubbing or absorption step to remove hydrochloric acid and other halo-acids from the combustion gases. Ash in the waste is not destroyed in the combustion process. Depending on its composition, ash will either exit as bottom ash, at the discharge end of a kiln or hearth for example, or as particulate matter (fly ash) suspended in the combustion gas stream. Particulate emissions from most hazardous waste combustion systems generally have particle diameters of less than 1 micron and require high-efficiency collection devices to minimize air emissions. In addition, scrubber systems provide an additional buffer against accidental releases of incompletely destroyed waste products as a result of poor combustion efficiency or combustion upsets, such as flameouts.

(4) Waste characteristics affecting performance.

(a) Liquid injection. In determining whether liquid injection is likely to achieve the same level of performance on an untested waste as on a previously tested waste, the Agency will compare dissociation bond energies of the constituents in the untested and tested waste. This parameter is being used as a surrogate indicator of activation energy which, as discussed previously, destabilized molecular bonds. In theory, the bond dissociation energy would be equal to the activation energy; however, in practice this is not always the case. Other energy effects (e.g., vibrational effects, the formation of intermediates, and interactions between different molecular bonds) may have a significant influence on activation energy.

Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine whether these parameters would provide a better basis for transferring treatment standards from an untested waste to a tested waste. These parameters include heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these were rejected for reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state. Heat of formation is used as a tool to predict whether reactions are likely to proceed; however, there are a significant number of hazardous constituents for which these data are not available. Use of kinetic data was rejected because these data are limited and could not be used to calculate free energy values (ΔG) for the wide range of hazardous constituents to be addressed by this rule. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct determination of whether a constituent will be destabilized.

(b) Rotary kiln/fluidized bed/fixed hearth. Unlike liquid injection, these incineration technologies also generate a residual ash. Accordingly, in determining whether these technologies are likely to achieve the same level of performance on an untested waste as on a previously tested waste, EPA would need to examine the waste characteristics that affect volatilization of organics from the waste, as well as destruction of the organics, once volatilized. Relative to volatilization, EPA will examine thermal conductivity of the entire waste and boiling point of the various constituents. As with liquid injection, EPA will examine bond energies in determining whether treatment standards for scrubber water residuals can be transferred from a tested waste to an untested waste. Below is a discussion of how EPA arrived at thermal conductivity and boiling point as the best method to assess volatilization of organics from the waste; the discussion relative to bond energies is the same for these technologies as for liquid injection and will not be repeated here.

(i) Thermal conductivity. Consistent with the underlying principles of incineration, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of rotary kiln, fluidized bed, and fixed hearth incineration, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given incinerator, heat transferred through various wastes by radiation is more a function of the design and type of incinerator than of the waste being treated. Accordingly, the type of waste treated will have a minimal impact on the amount of heat transferred by radiation. With regard to convection, EPA also believes that the type of heat transfer will generally be more a function of the type and design of incinerator than of the waste itself. However, EPA is examining particle size as a waste characteristic that may significantly impact the amount of heat transferred to a waste by convection and thus impact volatilization of the various organic compounds. The final type of heat transfer, conduction, is the one that EPA believes will have the greatest impact on volatilization of organic constituents. To measure this characteristic, EPA will use thermal conductivity; an explanation of this parameter, as well as how it can be measured, is provided below.

Heat flow by conduction is proportional to the temperature gradient across the material. The proportionality constant is a property of the material and is referred to as the thermal conductivity. (Note: The analytical method that EPA has identified for measurement of thermal conductivity is named "Guarded, Comparative, Longitudinal Heat Flow Technique"; it is described in Appendix C.) In theory, thermal conductivity would always provide a good indication of whether a constituent in an untested waste would be treated to the same extent in the primary incinerator chamber as the same constituent in a previously tested waste.

In practice, thermal conductivity has some limitations in assessing the transferability of treatment standards; however, EPA has not identified a parameter that can provide a better indication of heat transfer characteristics of a waste. Below is a discussion of both the limitations associated with thermal conductivity and the other parameters considered.

Thermal conductivity measurements, as part of a treatability comparison for two different wastes through a single incinerator, are most meaningful when applied to wastes that are homogeneous (i.e., major constituents are essentially the same). As wastes exhibit greater degrees of nonhomogeneity (e.g., significant concentration of metals in soil), then thermal conductivity becomes less accurate in predicting treatability because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance) and not heat flow through all parts of the waste.

BTU value, specific heat, and ash content were also considered for predicting heat transfer characteristics. These parameters can no better account for nonhomogeneity than can thermal conductivity; additionally, they are not directly related to heat transfer characteristics. Therefore, these parameters do not provide a better indication of the heat transfer that will occur in any specific waste.

(ii) Boiling point. Once heat is transferred to a constituent within a waste, then removal of this constituent from the waste will depend on its volatility. As a surrogate of volatility, EPA is using boiling point of the constituent. Compounds with lower boiling points have higher vapor pressures and therefore would be more likely to vaporize. The Agency recognizes that this parameter does not take into consideration the impact of other compounds in the waste on the boiling point of a constituent in a mixture; however, the Agency is not aware of a better measure of volatility that can easily be determined.

(5) Design and operating parameters.

(a) Liquid injection. For a liquid injection unit, EPA's analysis of whether the unit is well designed will focus on (1) the likelihood that sufficient energy is provided to the waste to overcome the activation level for breaking molecular bonds and (2) whether sufficient oxygen is present to convert the waste constituents to carbon dioxide and water vapor. The specific design parameters that the Agency will evaluate to assess whether these conditions are met are temperature, excess oxygen, and residence time. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

It is important to point out that, relative to the development of land disposal restriction standards, EPA is concerned with these design parameters only when a quench water or scrubber water residual is generated from treatment of a particular waste. If treatment of a particular waste in a liquid injection unit would not generate a wastewater stream, then the Agency, for purposes of land disposal treatment standards, would be concerned with only the waste characteristics that affect selection of the unit, not the above-mentioned design parameters.

(i) Temperature. Temperature is important in that it provides an indirect measure of the energy available (i.e., Btu/hr) to overcome the activation energy of waste constituents. As the design temperature increases, it is more likely that the molecular bonds will be destabilized and the reaction completed.

The temperature is normally controlled automatically through the use of instrumentation that senses the temperature and automatically adjusts the amount of fuel and/or waste being fed. The temperature signal transmitted to the controller can be simultaneously transmitted to a recording device, referred to as a strip chart, and thereby continuously recorded. To fully assess the operation of the unit, it is important to know not only the exact location in the incinerator at which the temperature is being monitored but also the location of the design temperature.

(ii) Excess oxygen. It is important that the incinerator contain oxygen in excess of the stiochiometric amount necessary to convert the organic compounds to carbon dioxide and water vapor. If insufficient oxygen is present, then destabilized waste constituents could recombine to the same or other BDAT list organic compounds and potentially cause the scrubber water to contain higher concentrations of BDAT list constituents than would be the case for a well-operated unit.

In practice, the amount of oxygen fed to the incinerator is controlled by continuous sampling and analysis of the stack gas. If the amount of oxygen drops below the design value, then the analyzer transmits a signal to the valve controlling the air supply and thereby increases the flow of oxygen to the afterburner. The analyzer simultaneously transmits a signal to a recording device so that the amount of excess oxygen can be continuously recorded. Again, as with temperature, it is important to know the location at which the combustion gas is being sampled.

(iii) Carbon monoxide. Carbon monoxide is an important operating parameter because it provides an indication of the extent to which the waste organic constituents are being converted to carbon dioxide and water vapor. An increase in the carbon monoxide level indicates that greater amounts of organic waste constituents are unreacted or partially reacted. Increased carbon monoxide levels can result from insufficient excess oxygen, insufficient turbulence in the combustion zone, or insufficient residence time.

(iv) Waste feed rate. The waste feed rate is important to monitor because it is correlated to the residence time. The residence time is associated with a specific Btu energy value of the feed and a specific volume of combustion gas generated. Prior to incineration, the Btu value of the waste is determined through the use of a laboratory devise known as a bomb calorimeter. The volume of combustion gas generated from the waste to be incinerated is determined from an analysis referred to as an ultimate analysis. This analysis determines the amount of elemental constituents present, which include carbon, hydrogen, sulfur, oxygen, nitrogen, and halogens. Using this analysis plus the total amount of air added, one can calculate the volume of combustion gas. After both the Btu content and the expected combustion gas volume have been determined, the feed rate can be fixed at the desired residence time. Continuous monitoring of the feed rate will determine whether the unit is being operated at a rate corresponding to the designed residence time.

(b) Rotary kiln. For this incineration, EPA will examine both the primary and secondary chamber in evaluating the design of a particular incinerator. Relative to the primary chamber, EPA's assessment of design will focus on whether sufficient energy is likely to be provided to the waste to volatilize the waste constituents. For the secondary chamber, analogous to the sole liquid injection incineration chamber, EPA will examine the same parameters discussed previously under liquid injection incineration. These parameters will not be discussed again here.

The particular design parameters to be evaluated for the primary chamber are kiln temperature, residence time, and revolutions per minute. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

(i) Temperature. The primary chamber temperature is important in that it provides an indirect measure of the energy input (i.e., Btu/hr) available for heating the waste. The higher the temperature is designed to be in a given kiln, the more likely it is that the constituents will volatilize. As discussed earlier under "Liquid injection," temperature should be continuously monitored and recorded. Additionally, it is important to know the location of the temperature sensing device in the kiln.

(ii) Residence time. This parameter is important in that it affects whether sufficient heat is transferred to a particular constituent in order for volatilization to occur. As the time that the waste is in the kiln is increased, a greater quantity of heat is transferred to the hazardous waste constituents. The residence time will be a function of the specific configuration of the rotary kiln, including the length and diameter of the kiln, the waste feed rate, and the rate of rotation.

(iii) Revolutions per minute (RPM). This parameter provides an indication of the turbulence that occurs in the primary chamber of a rotary kiln. As the turbulence increases, the quantity of heat transferred to the waste would also be expected to increase. However, as the RPM value increases, the residence time decreases, resulting in a reduction of the quantity of heat transferred to the waste. This parameter needs to be carefully evaluated because it provides a balance between turbulence and residence time.

(c) Fluidized bed. As discussed previously in the section on "Underlying Principles of Operation," the primary chamber accounts for almost all of the conversion of organic wastes to carbon dioxide, water vapor, and acid gas if halogens are present. The secondary chamber will generally provide additional residence time for thermal oxidation of the waste constituents. Relative to the primary chamber, the parameters that the Agency will examine in assessing the effectiveness of the design are temperature, residence time, and bed pressure differential. The first two were included in the discussion of the rotary kiln and will not be discussed here. The latter, bed pressure differential, is important in that it provides an indication of the amount of turbulence and, therefore, indirectly the amount of heat supplied to the waste. In general, as the pressure drop increases, both the turbulence and heat supplied increase. The pressure drop through the bed should be continuously monitored and recorded to ensure that the designed value is achieved.

(d) Fixed hearth. The design considerations for this incineration unit are similar to those for a rotary kiln with the exception that rate of rotation (i.e., RPM) is not an applicable design parameter. For the primary chamber of this unit, the parameters that the Agency will examine in assessing how well the unit is designed are the same as those discussed under "Rotary kiln"; for the secondary chamber (i.e., afterburner), the design and operating parameters of concern are the same as those previously discussed under "Liquid injection."

4. PERFORMANCE DATA BASE

This section discusses the available performance data associated with the demonstrated technology for K024 waste. Performance data include the constituent concentrations in untreated and treated waste samples, the operating data collected during treatment of the sampled waste, design values for the treatment technology, and data on waste characteristics that affect performance. EPA has presented all such data to the extent that they are available.

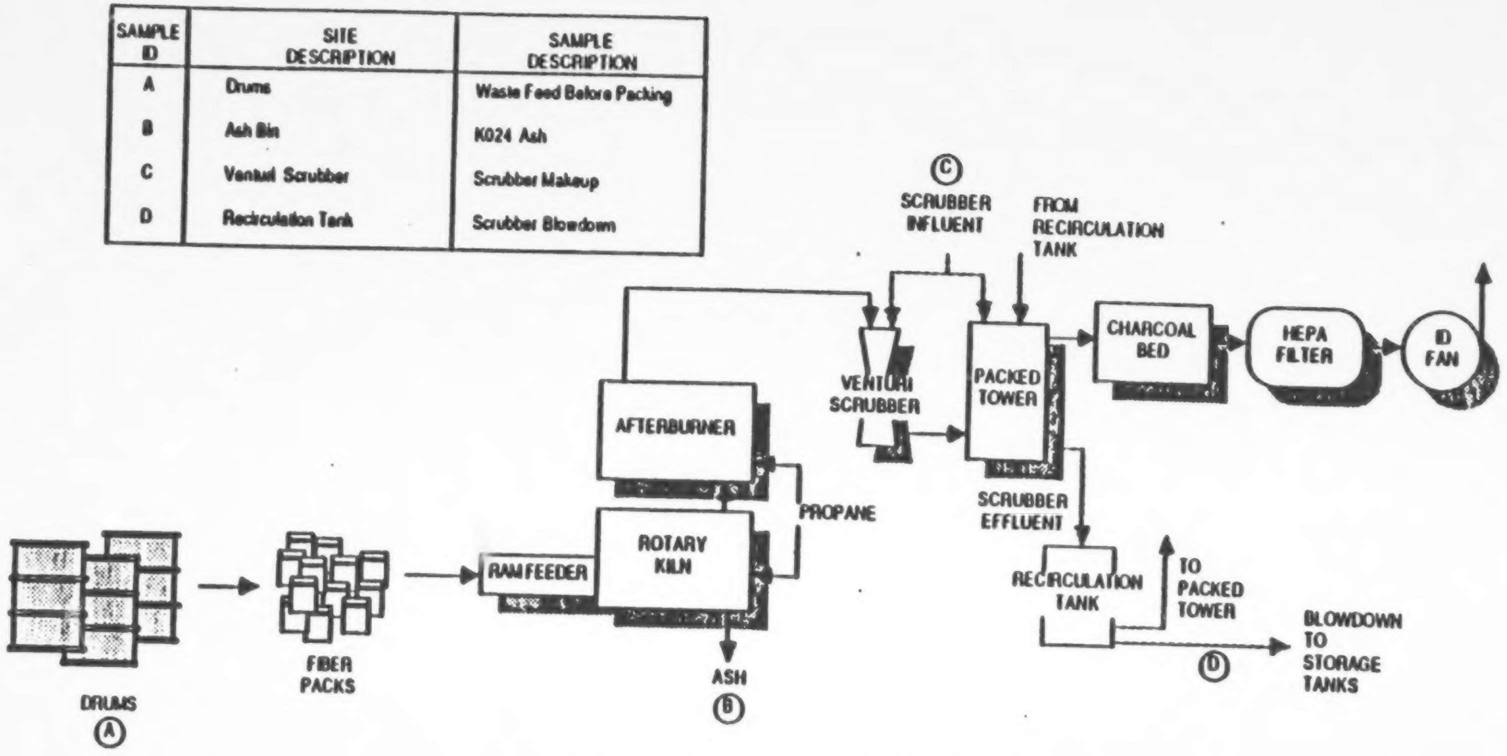
EPA's use of these data in determining the technology that represents BDAT, and in developing treatment standards, is described in Sections 5 and 7, respectively.

EPA tested rotary kiln incineration technology as part of the development of treatment standards for K024. Figure 4-1 at the end of this section, is the treatment process schematic.

During the treatment of K024 waste in the rotary kiln incinerator, two treatment residue streams are generated: a wastewater stream (i.e., scrubber water) and a nonwastewater stream (i.e., ash). Residue samples for ash and scrubber water were taken for analysis at sampling points B and C, respectively, and the raw untreated waste was sampled at sampling point A shown in Figure 4-1.

The analytical data collected by EPA for rotary kiln incineration are presented in Tables 4-1 through 4-4 at the end of this section. The treatment performance data show that in almost all cases the BDAT constituents are reduced to levels below the detection limits. Hence, it can be concluded that treatment is very effective.

The Agency has data on 8 sets of untreated waste samples, 6 kiln ash samples, and 10 scrubber water samples from an EPA incineration facility that show treatment of BDAT list organic constituents in K024 waste. These analytical data, collected during a test burn using rotary kiln incineration, have been reported in the K024 onsite engineering report (USEPA 1987b), along with design and operating information on the treatment system. The analytical data are presented in Tables 4-1 through 4-4 at the end of this section. These data show total waste concentrations for all BDAT list constituents in the untreated waste (Table 4-1), the scrubber water (Table 4-2), and the residual ash (Table 4-3). Total concentrations and TCLP leachate concentrations for metals in the ash are also shown (Table 4-4). Tables 4-5 through 4-9 present design and operating parameters of the CRF rotary kiln system.



SAMPLE ID	SITE DESCRIPTION	SAMPLE DESCRIPTION
A	Drums	Waste Feed Before Packing
B	Ash Bin	K024 Ash
C	Venturi Scrubber	Scrubber Makeup
D	Recirculation Tank	Scrubber Blowdown

DRUMS
Ⓐ
FIBER PACKS
RAM FEEDER
ROTARY KILN
AFTERBURNER
PROPANE
ASH
Ⓑ
Ⓒ
SCRUBBER INFLUENT
FROM RECIRCULATION TANK
VENTURI SCRUBBER
PACKED TOWER
SCRUBBER EFFLUENT
RECIRCULATION TANK
TO PACKED TOWER
Ⓓ
BLOWDOWN TO STORAGE TANKS
CHARCOAL BED
HEPA FILTER
ID FAN

Figure 4-1 U.S. EPA Rotary Kiln Configuration and Feed/Residuals Sampling Points During the K024 Test Burn

Table 4-1 Rotary Kiln Incineration - EPA-Collected Total Concentration Data for Untreated Waste

Constituent	Untreated waste concentration							
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5[a]	Sample 6[a]	Sample 7[a]	Sample 8[a]
Volatile organics (ppm)								
Chloromethane	<10	32	<10	40	<10	10	<10	<10
Methyl ethyl ketone	240	200	210	210	680	600	690	700
Semivolatile organics (ppm)								
Phthalic acid[b,c]	220,000[d]	83,000[d]	110,000[d]	13,000[d]	NA	NA	NA	NA
Anthracene dione[b]	6,700	5,600	6,300	5,900	NA	NA	NA	NA
Metals								
(Not analyzed)								

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[a] Using methanol extract, a methanol blank for methyl ethyl ketone was reported as 770 ppm.

[b] Non-BDAT parameter.

[c] Phthalic acid is used as a surrogate constituent for phthalic anhydride since phthalic anhydride is converted to phthalic acid during the chemical analysis.

[d] Memo to Fred Hall, PEI Associated, Cincinnati, Ohio, from Patrick Meehan, Radian Corp., Austin, Texas, dated December 15, 1987.

NA = Not analyzed

Reference: EPA 1987b, Tables 6-5, 6-6, and 6-10.

Table 4-2 Rotary Kiln Incineration - EPA-Collected Total Concentration Data for Scrubber Water

Constituent	Scrubber water concentration									
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Volatile organics (μg/l)										
Chloromethane	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
1,2-Dibromo-3-chloropropane	12	<10	<10	<10	<10	<10	<10	<10	<10	<10
Dichlorodifluoromethane	<10	<10	<10	<10	23	<10	<10	<10	<10	<10
Methy ethyl ketone	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Semivolatile organics (μg/l)										
Phthalic acid (surrogate for phthalic anhydride)	<160[a]	<160	<160	<160	<160	<160	<160	<160	<160	<160
Anthracene dione	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
Metals (mg/l)										
Arsenic	0.22	0.063	0.047	0.041	0.066	0.059	<0.02	0.022	0.024	0.035
Barium	0.10	0.077	0.11	0.16	0.41	0.039	0.35	0.037	0.097	<0.01
Cadmium	0.082	0.072	0.038	0.025	<0.02	<0.02	<0.02	<0.02	<0.02	<0.025
Chromium	0.036	0.096	<0.035	<0.035	<0.035	<0.53	<0.53	<0.035	0.65	<0.035
Copper	0.81	0.118	0.32	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	0.11	0.12	0.13	0.13	0.10	0.10	<0.075	<0.075	<0.075	<0.075
Lead	2.0	5.2	10.0	9.2	16	1.7	2.7	1.5	1.4	1.7
Zinc	1.5	1.9	1.7	1.4	1.3	2.0	0.33	0.70	0.79	1.1

[a] Memo to Fred Hall, PEI Associated, Cincinnati, Ohio, from Patrick Meehan, Radian Corp., Austin, Texas, dated December 15, 1987.

Reference: EPA 1987b, Tables 6-3, 6-7 to 6-9, and 6-14.

Table 4-3 Rotary Kiln Incineration - EPA-Collected Total Concentration Data for Ash

Constituent	Ash concentration					
	Sample 1	Sample 2	Sample 3	Sample 4[a]	Sample 5[a]	Sample 6[a]
Volatile organics (μg/g)						
Chloromethane	<10	<10	<10	<10	<10	<10
Methyl ethyl ketone	<50	<50	<50	1100	780	440
Semivolatile organics (μg/g)						
Phthalic acid (surrogate for phthalic anhydride)	<8.2	<8.2	<8.2	NA	NA	NA
Anthracene dione	<2.5	<2.5	<2.5	NA	NA	NA
Metals (μg/g)						
Arsenic	12	2.5	2.1	Not analyzed		
Barium	3900	85	35			
Cadmium	2.2	<1.5	<1.5			
Chromium	20	45	52			
Copper	46	25	21			
Nickel	11	44	55			
Lead	1100	110	20			
Vanadium	64	10	<10			
Zinc	170	110	29			

NA = Not analyzed

[a] Use of methanol extract; a methanol blank for methyl ethyl ketone was reported as 770 μg/g.

Reference: EPA 1987b, Tables 6-4 to 6-6 and 6-12.

Table 4-4 Total and TCLP Metals Analyses Data for Ash

Constituent	Ash concentration							
	Sample 1		Sample 2		Sample 3		Blank	
	Total (µg/g)	TCLP (ppm)	Total (µg/g)	TCLP (ppm)	Total (µg/g)	TCLP (ppm)	Total	TCLP (ppm)
Arsenic	12	<1.5	2.5	<1.5	2.1	<1.5	NA	<1.5
Barium	3900	0.38	85	0.18	35	0.084	NA	0.34
Cadmium	2.2	<0.015	<1.5	0.004	<1.5	<0.015	NA	<0.015
Chromium	20	<0.045	45	0.37	52	0.051	NA	<0.045
Copper	46	0.14	25	<0.05	21	<0.05	NA	0.37
Nickel	11	<0.10	44	1.5	55	0.11	NA	<0.10
Lead	1100	2.3	110	<0.25	20	<0.25	NA	<0.25
Thallium	1.0	<0.45	1.0	<0.45	1.0	0.17	NA	<0.45
Zinc	170	0.30	110	1.6	29	<0.10	NA	0.26

NA = Not available

Reference: EPA 1987b, Tables 6-12 and 6-13.

Table 4-5 Design Characteristics of the CRF Rotary Kiln System

Characteristics of the kiln main chamber		
Length	2.44 m (8 ft)	
Diameter	1.22 m (4 ft)	
Chamber volume	2.88 m^3 (100 ft^3)	
Rotation	Clockwise or counterclockwise 0.1 to 1.5 rpm	
Construction	0.63 cm (0.25 in.) thick cold rolled steel	
Refractory	12.7 cm (5 in.) thick high-alumina castable refractory, variable depth to produce a frustroconical effect for moving inerts	
Solids retention time	1 h (at 0.5 rpm)	
Burner	John Zink Model RW3I-FL	
Primary fuel	Propane	
Feed system	Liquids:	Front face, water-cooled lance with positive-displacement pump
	Semiliquids:	Front face, water-cooled lance with double-diaphragm pump
	Solids:	Ram feeder or metered twin-auger screw feeder
Temperature[a]	1000°C (1832°F)	
Characteristics of the afterburner chamber		
Length	3.05 m (10 ft)	
Diameter	0.91 m (3 ft)	
Chamber volume	2.096 m^3 (74 ft^3)	

Table 4-5 (Continued)

Construction	0.63-cm (0.25-in.) thick cold rolled steel
Refractory	15.24-cm (6-in.) thick high-alumina castable refractory
Retention time	Depends on temperature and excess air (1.2 to 2.5 sec)
Burner	Iron Fireman, Model C-120-G-SMG, rated at 530 kW (1.8×10^6 Btu/h or 31.6 MJ/s)
Primary fuel	Propane
Temperature	1200°C (2200°F) maximum operating
Characteristics of the air pollution control system	
System capacity	Inlet gas flow of 106.8 m^3/min (3773 acfm) at 1200°C (2200°F) and 101 kPa (14.7 psia)
Pressure drop	Venturi 7.5 kPa (30 in. WC)[b] Packed tower 1.0 kPa (4 in. WC)
Liquid flow (nominal)	Venturi 77.2 l/min (20.4 gal/min) at 69 kPA (10 psig) Tower 115 l/min (30 gal/min) at 69 kPa (10 psig) Blowdown 7.6 to 9.5 l/min (2 to 2.5 gpm)
pH control	Feedback control by NaOH solution addition
Packing	Saddles

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[a] Operating temperatures in excess of 1837°F have been generated. Waste treatment effectiveness should not be affected under these conditions.

[b] Operating pressure drops of 30 to 35 in. H_2O across the scrubber and up to 8.2 in.H_2O across the packed tower have been used.

Reference: EPA 1987b, Table 3-1.

Table 4-6 Incinerator Operating Parameters, Rotary Kiln

Test date	Propane range (average)		Waste feed rate (lb/h)	Combustion air feed rate (scfm)	Exit temperature range (average) (°F)	Rotation speed (rpm)	Pressure (draft) (in. H_2O)
	Feed rate (scfh)	Heat input (10^6 Btu/h)					
3/17/87	336-424 (366)	0.822-1.040 (0.935)	53[a]	124	1573° - 1754° (1707°)	0.2	-0.12
3/18/87	282-476 (320)	0.690-1.170 (0.784)	107[b]	124	1713° - 2026° (1898°)	0.2	-0.12
3/19/87	202-342 (311)	0.496-0.839 (0.763)	104[c]	124	1510° - 1953° (1786°)	0.2	-0.12

[a] One fiber pack containing about 4.5 lb waste fed every 5 minutes.
[b] One fiber pack containing about 4.5 lb waste fed every 2.5 minutes.
[c] Two fiber packs containing about 4.5 lb waste fed every 5 minutes.
Reference: Onsite Engineering Report, EPA 1987b, Table B-1.

Table 4-7 Incinerator Operating Parameters, Afterburner

Test date	Afterburner parameter range (average)							
	Propane range		Combustion air feed rate (scfm)	Exit temperature (°F)	Pressure (draft) (in. H_2O)	Exit Gas		
	Feed rate (scfh)	Heat input (10^6 Btu/h)				O_2(%)	CO_2(%)[b]	CO(ppm)[a]
3/17/87	367-561 (488)	0.901-1.377 (1.196)	111-118 (113)	1963° - 2078° (2055°)	 (-0.12)	5	9	<10-100[b] <10
3/18/87	378-564 (440)	0.925-1.381 (1.078)	118-124 (120)	1894° - 2155° (2025°)	-0.2 to -0.1 (-0.15)	4	10	<10-100[b] <10
3/19/87	367-636 (311)	0.897-1.599 (1.172)	 (111)	1921° - 2091° (2014°)	-0.2 to -0.1 (-0.15)	5	10	<10-100[b] <10

[a] Instrument limit on CO_2 is 10 percent; on CO, 100 ppm; actual values therefore could be higher than the peak values shown.

[b] One or more CO spikes from 40 to 100 ppm during test period.

Reference: EPA 1987b, Table B-2.

Table 4-8 Incinerator Operating Parameters, Scrubber System (Acurex)

	Scrubber system parameter range (average)								
	Venturi		Packed tower		Scrubber liquid		Blowdown		
Test date	Liquid flow rate (gal/min)	Delta P (in. H_2O)	Liquid flow rate (gal/min)	Delta P (in. H_2O)	pH	Temperature (°F)	Flow rate (gal/min)	Temperature (°F)	Makeup water feed rate (gal/min)
3/17/87		25-42		5.0-10		147° - 165°		71-102	5.0-10
	19	(35)	(31)	(6.9)	(6.2)	(160°)	2.1	(681)	(6.9)
3/18/87		20-43	28-29	5.0-10	6.0-6.2	148° - 166°	1.8-2.4	84-112	5.0-10
	19	(34)	(29)	(7.6)	6.1	(158°)	(2.3)	(94)	(7.6)
3/19/87		20-38	29-30	6.1-10	5.0-5.1	153° - 165°		86-119	6.1-10
	19	(34)	(29)	(8.2)	5.1	(161°)	2.2	(102)	(8.2)

Reference: EPA 1987b, Table B-3

Table 4-9. Incinerator Operating Parameters, Scrubber Exit and Stack

	Operating conditions range (average)									
	Scrubber exit (prior to charcoal bed)					Stack (to atmosphere)				
Test date	Temperature (°F)	Flow rate (dscfm)	O_2(%)	CO_2(%)	CO (ppm)	Temperature (°F)	Flow rate[a] (dscfm)	O_2 (%)	CO_2 (%)	CO (ppm)
3/17/87	164° - 173° (170°)	708	10.5	6.0	<10	163° - 170° (167°)	933	10.5	6.0	<10
3/18/87	164° - 173° (169°)	735	10.0	8.1	<10	163° - 170° (168°)	679	10.0	8.1	<10
3/19/87	160° - 174° (170°)	670	10.5	6.2	<10	161° - 172° (168°)	734	10.5	6.2	<10

[a] As measured by the stack MM5 train.

[b] See Figure 2-1 for location of monitoring points.

Reference: EPA 1987b, Table B-4.

5. IDENTIFICATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section explains EPA's determination of the best demonstrated available technology (BDAT) for K024 waste. As discussed in Section 1, the BDAT for a waste must be the "best" of the "demonstrated" technologies; the BDAT must also be "available." In general, the technology that constitutes "best" is determined after screening the available data from each demonstrated technology, adjusting these data for accuracy, and comparing the performance of each technology to that of the others. If only one technology is identified as demonstrated, this technology is considered "best." To be "available" a technology (1) must be commercially available and (2) must provide substantial treatment.

Included in this section is a discussion on how the Agency selected a BDAT technology based on the treatment/destruction technology performance data developed during the treatment demonstration and laboratory analysis. All the analytical data generated specific to the BDAT constituents are screened using the acceptable design and operating characteristics of the treatment technology, the quality assurance/ quality control objectives of the BDAT treatment standards development process, and the statistical analysis methods used to assess the data quality. Performance data that did not meet any or all of these screening criteria are deleted from consideration as BDAT. The remaining performance data are corrected for accuracy, precision, and recovery to account for any analytical problems related to interferences associated with the sample matrix. Finally, in cases where the Agency has data on treatment of the same wastes using more than one applicable and demonstrated technology, the analysis of variance (ANOVA) test is used to determine which technology provides the best performance data and treatment efficiencies.

5.1 Data Screening

The available treatment data for K024 were reviewed and assessed with regard to the design and operation of the treatment system, the quality assurance/quality control objectives that must be met during the data generation and analysis, and the statistical analysis performed to assess treatment efficiencies based on the treatment performance data. Data that did not meet data quality objectives were regarded as "unacceptable" data and were deleted. Only the "acceptable" performance data were used for developing BDAT. The BDAT development objectives are given in Section 1 of this report.

For rotary kiln incineration, analytical data are reported for 8 untreated waste samples, 10 scrubber water samples, and 6 ash samples that were collected. All the available data have been used for the development of treatment standards. The Agency believes the incineration data represent acceptable performance of rotary kiln incineration, and the data were used for the development of treatment standards for K024.

5.2 Data Accuracy

After the screening tests, EPA adjusted the data values based on the analytical recovery values to take into account analytical interferences associated with the chemical makeup of the treated sample. In developing recovery data (also referred to as accuracy data), EPA first analyzed the waste for a constituent and then added a known amount of the same constituent (i.e., spike) to the waste material. The total amount recovered after spiking minus the initial concentration in the sample, divided by the amount added, is the recovery value. The analytical data were adjusted for accuracy using the lowest recovery value for each constituent. These adjusted values for rotary kiln incineration were then used to determine BDAT for K024.

5.3 Analysis of Variance

In cases were the Agency has data on treatment of the same or similar wastes using more than one technology, EPA conducts an analysis of variance (ANOVA) test to determine whether one of the technologies performs significantly better than the others. In cases where a particular treatment technology performs better, the treatment standard will be based on this best technology.

In the case of K024, no ANOVA test was necessary since rotary kiln incineration was the only destruction technology for which data were available.

5.4 Determination of BDAT

K024 waste is an organic nonwastewater for the purpose of determining the applicability of the BDAT treatment standards, since wastewaters are defined as wastes containing less than 1 percent (weight basis) filterable solids and less than 1 percent (weight basis) total organic carbon. However, the demonstrated technology for K024 nonwastewaters produces both nonwastewater and wastewater residuals. BDAT must therefore be identified for both types of waste streams.

5.4.1 Nonwastewaters

The only demonstrated technology for this waste is incineration. The Agency has data on incineration of K024 nonwastewaters only for rotary kiln incineration. It is therefore not possible to compare rotary kiln incineration with other forms of incineration, such as fluidized bed. However, the Agency has no reason to expect that fluidized bed incineration would provide better treatment than rotary kiln incineration because operating temperatures in fluidized bed units are lower than those in rotary kilns. EPA therefore has determined that incineration in a rotary kiln is the best demonstrated technology for K024 nonwastewaters.

Rotary kiln incineration is commonly available commercially. As shown in the performance data in Section 4.0, it also achieves substantial treatment. Phthalic acid in the untreated waste* of between 13,000 and 220,000 ppm is treated to nondetectable levels in both the incinerator ash and the incinerator scrubber water. Methyl ethyl ketone levels of 200 and 700 ppm in the untreated waste are also treated to nondetectable levels in both ash and scrubber waters.

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* As noted elsewhere, phthalic acid, a non-BDAT parameter, is used as a surrogate for phthalic anhydride because phthalic anhydride is converted to phthalic acid during chemical analysis.

EPA therefore concludes that rotary kiln incineration is the best demonstrated available technology (BDAT) for treatment of K024 nonwastewaters.

As noted, incineration produces one nonwastewater residual, incinerator ash. Since organic constituent levels in this residual are below detection limits, EPA concludes that no further treatment could improve upon the levels of performance achieved by rotary kiln incineration alone and that no further treatment is necessary. Rotary kiln incineration is therefore also BDAT for nonwastewater residuals from incineration of K024 nonwastewaters.

5.4.2 Wastewaters

Scrubber water is the other residual produced by incineration of K024 nonwastewaters. Since performance data indicate that levels of phthalic acid and other constituent organics in this wastewater are below detection limits, the Agency concludes that no further treatment of this residual stream could improve upon the level of performance achieved by rotary kiln incineration alone and that no further treatment is required. Rotary kiln incineration is therefore BDAT for wastewater residuals from incineration of K024 nonwastewaters.

6. SELECTION OF REGULATED CONSTITUENTS

This section discusses the methodology used to select regulated constituents for K024. As discussed in Section 1, the Agency has developed a list of hazardous constituents (Table 1-1) from which the pollutants to be regulated are selected. The list is a "growing list" that does not preclude the addition of new constituents as additional key parameters are identified. The list is divided into the following categories: volatile organics, semivolatile organics, metals, other inorganics, organochlorine pesticides, phenoxyacetic acid herbicides, organophosphorous pesticides, PCBs, and dioxins and furans. The constituents in each category have similar chemical properties and are expected to behave similarly during treatment, with the exception of the inorganics.

The selection process resulted primarily in reducing the list of 251 BDAT constituents to those BDAT constituents that are found in the untreated wastes at significant (i.e., treatable) concentrations and those that were prioritized for regulation based on difficulties encountered or expected during treatment. Where applicable, certain other BDAT constituents are not regulated because the waste treatment performance data show that these would be controlled in the course of achieving the limit set for other constituents.

This section describes the step-by-step process used to select the pollutants to be regulated. The selected pollutants must be present in the untreated waste and must be treatable by the chosen BDAT, as discussed in Section 5.

6.1 Identification of Major Constituents in the Untreated Waste

The analytical data gathered or generated as part of the BDAT program were analyzed and reviewed to select major constituents in the untreated waste. The selection of these constituents was based primarily on the presence of particular constituents in the waste at a concentration at or above the detection limit in the untreated waste. As a general rule, any constituent present in the waste at a concentration above the analytical detection limit would be eligible for selection.

For example, phthalic acid, which is a surrogate for phthalic anhydride in the untreated waste, is detected at or above the 2500-ppm level and therefore is identified as a major constituent in K024 untreated waste. Using a similar selection process, other major constituents are selected. These constituents and their concentrations identified in the untreated K024 are listed in Table 6-1 at the end of this section.

6.2 Comparison of the Untreated and Treated Waste Data for the Major Constituents

A comparison of analytical data for the major constituents in the untreated and treated waste demonstrated whether the major constituents were significantly reduced and the concentrations of the major constituents were below the detection limits or practical quantitation limits (PQLs).

When the concentrations of constituents were not below the detection limit, the comparison was based on percent reduction. The reduction is defined as the ratio of the concentration of the major constituent in the untreated waste to the concentration in the treated waste. For constituents present in the treated waste but not detected in the untreated waste, it was assumed that the constituent was present in the untreated waste at or near the detection limit. This assumption is based on the likelihood of masking of the constituent by other constituents in the untreated waste.

In general, where the concentration of a major constituent in the waste was reduced by a factor of less than 10 after the treatment of the waste, the Agency concluded that this reduction in constituent concentration may not be significant treatment and that, therefore, further analysis of the analytical data is required to determine whether the reduction that has been achieved is significant. A statistical method known as analysis of variance (ANOVA), which is discussed in Section 1, is used to determine statistically the significance of constituent concentrations. Table 6-2, at the end of this section, compares the analytical data for untreated and treated waste for chloromethane, methyl ethyl ketone, phthalic anhydride, anthracene dione, and BDAT metals.

EPA recognizes that some BDAT metals were detected in the residue wastewater and nonwastewater. The TCLP for nonwastewater (i.e., ash) did not show that BDAT metals are present in the ash at treatable concentrations. The average TCLP concentration in treated nonwastewater for any given metal is below treatable levels. In contrast, two BDAT metals were found in the residue wastewater at levels that may be considered treatable. EPA has not chosen to regulate metals for K024 at this time, but reserves the right to do so at a later date.

Even though methyl ethyl ketone was found in treated nonwastewater (i.e., ash), as seen from Table 6-2, the concentration was very similar to the level of 770 ppm detected in methanol blank. This suggests that methyl ethyl ketone does not exist in nonwastewater. In addition, EPA believes that methyl ethyl ketone is much more volatile than the constituent that is being regulated and that, if present, methyl ethyl ketone would be adequately controlled.

6.3 Evaluation of Waste Characteristics Affecting Performance and Other Related Factors

The waste characteristics that would affect treatment performance, discussed in Section 3, are used to evaluate the constituents to determine whether any additional constituents must be selected for regulation. Such an evaluation is generally performed when a significant number of constituents are identified for potential regulation, in order to shorten the list of regulated pollutants to those that, when treated, are likely to ensure that many others in the potential list are treated. In other words, the constituents that are most difficult to treat are selected, based on the waste characteristics affecting performance of the technology. For example, aniline is less volatile than benzene, and therefore it is likely to be more difficult to remove by thermal processes than benzene. Hence, aniline might be regulated if it were inadequately removed. In the case of K024 waste, no additional constituents were added to the list of constituents already considered for regulation.

6.4 Selection of Regulated Constituents

Phthalic anhydride is selected as the only regulated constituent for K024 because this constituent is present in the untreated waste at a 5 percent or higher concentration while all other BDAT constituents are present at nondetectable levels. This constituent cannot easily be analyzed, in that the analytical method readily hydrolyzes the compound to phthalic acid. Therefore, phthalic acid, although not listed as a hazardous constituent in Part 261 Appendix VIII, is being regulated as a surrogate for phthalic anhydride. The Agency detected BDAT metals at potentially treatable concentrations in the wastewater residue (i.e., scrubber water) from incineration. At this time, the Agency has decided not to regulate metals in the wastewater, but reserves the right to consider regulation of BDAT metals in the future.

Table 6-1 Status of BDAT List Constituent Presence in Untreated K024 Waste

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Volatile organics		
222.	Acetone	NA	
1.	Acetonitrile	NA	
2.	Acrolein	NA	
3.	Acrylonitrile	NA	
4.	Benzene	NA	
5.	Bromodichloromethane	NA	
6.	Bromomethane	NA	
223.	n-Butyl alcohol	NA	
7.	Carbon tetrachloride	NA	
8.	Carbon disulfide	NA	
9.	Chlorobenzene	NA	
10.	2-Chloro-1,3-butadiene	NA	
11.	Chlorodibromomethane	NA	
12.	Chloroethane	NA	
13.	2-Chloroethyl vinyl ether	NA	
14.	Chloroform	NA	
15.	Chloromethane	<10-40[b]	
16.	3-Chloropropene	NA	
17.	1,2-Dibromo-3-chloropropane	NA	
18.	1,2-Dibromoethane	NA	
19.	Dibromomethane	NA	
20.	trans-1,4-Dichloro-2-butene	NA	
21.	Dichlorodifluoromethane	NA	
22.	1,1-Dichloroethane	NA	
23.	1,2-Dichloroethane	NA	
24.	1,1-Dichloroethylene	NA	
25.	trans-1,2-Dichloroethene	NA	
26.	1,2-Dichloropropane	NA	
27.	trans-1,3-Dichloropropene	NA	
28.	cis-1,3-Dichloropropene	NA	
29.	1,4-Dioxane	NA	
224.	2-Ethoxyethanol	NA	
225.	Ethyl acetate	NA	
226.	Ethyl benzene	NA	
30.	Ethyl cyanide	NA	
227.	Ethyl ether	NA	
31.	Ethyl methacrylate	NA	
214.	Ethylene oxide	NA	
32.	Iodomethane	NA	
33.	Isobutyl alcohol	NA	
228.	Methanol	NA	
34.	Methyl ethyl ketone	NA	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Volatile organics (continued)		
229.	Methyl isobutyl ketone	NA	
35.	Methyl methacrylate	NA	
37.	Methacrylonitrile	NA	
38	Methylene chloride	NA	
230.	2-Nitropropane	NA	
39.	Pyridine	NA	
40.	1,1,1,2-Tetrachloroethane	NA	
41	1,1,2,2-Tetrachloroethane	NA	
42.	Tetrachloroethene	NA	
43.	Toluene	NA	
44.	Tribromomethane	NA	
45.	1,1,1-Trichloroethane	NA	
46.	1,1,2-Trichloroethane	NA	
47.	Trichloroethene	NA	
48.	Trichloromonofluoromethane	NA	
49.	1,2,3-Trichloropropane	NA	
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	NA	
50.	Vinyl chloride	NA	
215.	1,2-Xylene	NA	
216.	1,3-Xylene	NA	
217.	1,4-Xylene	NA	
	Semivolatile organics		
51.	Acenaphthalene	NA	
52.	Acenaphthene	NA	
53.	Acetophenone	NA	
54.	2-Acetylaminofluorene	NA	
55.	4-Aminobiphenyl	NA	
56.	Aniline	NA	
57.	Anthracene	NA	
58.	Aramite	NA	
59.	Benz(a)anthracene	NA	
218.	Benzal chloride	NA	
60.	Benzenethiol	NA	
61.	Deleted	NA	
62.	Benzo(a)pyrene	NA	
63.	Benzo(b)fluoranthene	NA	
64.	Benzo(ghi)perylene	NA	
65.	Benzo(k)fluoranthene	NA	
66.	p-Benzoquinone	NA	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile organics (continued)		
67.	Bis(2-chloroethoxy)methane	NA	
68.	Bis(2-chloroethyl)ether	NA	
69	Bis(2-chloroisopropyl)ether	NA	
70.	Bis(2-ethylhexyl)phthalate	NA	
71.	4-Bromophenyl phenyl ether	NA	
72.	Butyl benzyl phthalate	NA	
73.	2-sec-Butyl-4,6-dinitrophenol	NA	
74.	p-Chloroaniline	NA	
75.	Chlorobenzilate	NA	
76.	p-Chloro-m-cresol	NA	
77.	2-Chloronaphthalene	NA	
78.	2-Chlorophenol	NA	
79.	3-Chloropropionitrile	NA	
80.	Chrysene	NA	
81.	ortho-Cresol	NA	
82.	para-Cresol	NA	
232.	Cyclohexanone	NA	
83.	Dibenz(a,h)anthracene	NA	
84.	Dibenzo(a,e)pyrene	NA	
85.	Dibenzo(a,i)pyrene	NA	
86.	m-Dichlorobenzene	NA	
87.	o-Dichlorobenzene	NA	
88.	p-Dichlorobenzene	NA	
89.	3,3'-Dichlorobenzidine	NA	
90.	2,4-Dichlorophenol	NA	
91.	2,6-Dichlorophenol	NA	
92.	Diethyl phthalate	NA	
93.	3,3'-Dimethoxybenzidine	NA	
94.	p-Dimethylaminoazobenzene	NA	
95.	3,3'-Dimethylbenzidine	NA	
96.	2,4-Dimethylphenol	NA	
97.	Dimethyl phthalate	NA	
98.	Di-n-butyl phthalate	NA	
99.	1,4-Dinitrobenzene	NA	
100.	4,6-Dinitro-o-cresol	NA	
101.	2,4-Dinitrophenol	NA	
102.	2,4-Dinitrotoluene	NA	
103.	2,6-Dinitrotoluene	NA	
104.	Di-n-octyl phthalate	NA	
105.	Di-n-propylnitrosamine	NA	
106.	Diphenylamine	NA	
219.	Diphenylnitrosamine	NA	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile Organics (continued)		
107.	1,2-Diphenylhydrazine	NA	
108.	Fluoranthene	NA	
109.	Fluorene	NA	
110.	Hexachlorobenzene	NA	
111.	Hexachlorobutadiene	NA	
112.	Hexachlorocyclopentadiene	NA	
113.	Hexachloroethane	NA	
114.	Hexachlorophene	NA	
115.	Hexachloropropene	NA	
116.	Indeno(1,2,3-cd)pyrene	NA	
117.	Isosafrole	NA	
118.	Methapyrilene	NA	
119.	3-Methylcholanthrene	NA	
120.	4,4'-Methylenebis (2-chloroaniline)	NA	
36.	Methyl methanesulfonate	NA	
121.	Naphthalene	NA	
122.	1,4-Naphthoquinone	NA	
123.	1-Naphthylamine	NA	
124.	2-Naphthylamine	NA	
125.	p-Nitroaniline	NA	
126.	Nitrobenzene	NA	
127.	4-Nitrophenol	NA	
128.	N-Nitrosodi-n-butylamine	NA	
129.	N-Nitrosodiethylamine	NA	
130.	N-Nitrosodimethylamine	NA	
131.	N-Nitrosomethylethylamine	NA	
132.	N-Nitrosomorpholine	NA	
133.	N-Nitrosopiperidine	NA	
134.	n-Nitrosopyrrolidine	NA	
135.	5-Nitro-o-toluidine	NA	
136.	Pentachlorobenzene	NA	
137.	Pentachloroethane	NA	
138.	Pentachloronitrobenzene	NA	
139.	Pentachlorophenol	NA	
140.	Phenacetin	NA	
141.	Phenanthrene	NA	
142.	Phenol	NA	
220.	Phthalic acid (used as a surrogate for phthalic anhydride)	13,000-22,000[c]	
143.	2-Picoline	NA	
144.	Pronamide	NA	
145.	Pyrene	NA	
146.	Resorcinol	NA	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile organics (continued)		
147.	Safrole	NA	
148.	1,2,4,5-Tetrachlorobenzene	NA	
149.	2,3,4,6-Tetrachlorophenol	NA	
150.	1,2,4-Trichlorobenzene	NA	
151.	2,4,5-Trichlorophenol	NA	
152.	2,4,6-Trichlorophenol	NA	
153.	Tris(2,3-dibromopropyl) phosphate	NA	
	Anthracene dione[d]	5,400-6,700	
	Metals		
154.	Antimony	NA	
155.	Arsenic	NA	
156.	Barium	NA	
157.	Beryllium	NA	
158.	Cadmium	NA	
159.	Chromium (total)	NA	
221.	Chromium (hexavalent)	NA	
160.	Copper	NA	
161.	Lead	NA	
162.	Mercury	NA	
163.	Nickel	NA	
164.	Selenium	NA	
165.	Silver	NA	
166.	Thallium	NA	
167.	Vanadium	NA	
168.	Zinc	NA	
	Inorganics other than metals		
169.	Cyanide	NA	
170.	Fluoride	NA	
171.	Sulfide	NA	
	Organochlorine pesticides		
172.	Aldrin	NA	
173.	alpha-BHC	NA	
174.	beta-BHC	NA	
175.	delta-BHC	NA	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Organochlorine pesticides (continued)		
176.	gamma-BHC	NA	
177.	Chlordane	NA	
178.	DDD	NA	
179.	DDE	NA	
180.	DDT	NA	
181.	Dieldrin	NA	
182.	Endosulfan I	NA	
183.	Endosulfan II	NA	
184.	Endrin	NA	
185.	Endrin aldehyde	NA	
186.	Heptachlor	NA	
187.	Heptachlor epoxide	NA	
188.	Isodrin	NA	
189.	Kepone	NA	
190.	Methoxyclor	NA	
191.	Toxaphene	NA	
	Phenoxyacetic acid herbicides		
192.	2,4-Dichlorophenoxyacetic acid	NA	
193.	Silvex	NA	
194.	2,4,5-T	NA	
	Organophosphorous insecticides		
195.	Disulfoton	NA	
196.	Famphur	NA	
197.	Methyl parathion	NA	
198.	Parathion	NA	
199.	Phorate	NA	
	PCBs		
200.	Aroclor 1016	NA	
201.	Aroclor 1221	NA	
202.	Aroclor 1232	NA	
203.	Aroclor 1242	NA	
204.	Aroclor 1248	NA	
205.	Aroclor 1254	NA	
206.	Aroclor 1260	NA	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Dioxins and furans		
207.	Hexachlorodibenzo-p-dioxins	NA	
208.	Hexachlorodibenzofurans	NA	
209.	Pentachlorodibenzo-p-dioxins	NA	
210.	Pentachlorodibenzofurans	NA	
211.	Tetrachlorodibenzo-p-dioxins	NA	
212.	Tetrachlorodibenzofurans	NA	
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	NA	

NA = Not analyzed.

[a] Where concentrations are shown, units are mg/kg.

[b] Methyl ethyl ketone concentration in methanol blank reported as 770 ppm.

[c] Memo to Fred Hall, PEI Associates, Cincinnati, Ohio, from Patrick Meehan, Radian Corporation, Austin, Texas, dated December 15, 1987.

[d] Non-BDAT parameter.

Reference: EPA 1987b, Tables 6-4 to 6-6.

Table 6-2 Comparison of Major Constituents in Untreated and Treated K024 Waste

		Concentration range (ppm)					
		Untreated waste		Treated waste			
				Scrubber water		Ash	
	Constituent	Composite	TCLP	Composite	TCLP	Composite	TCLP
Volatile organics							
15.[a]	Chloromethane	<10 - 40	NA	<10[b]	NA	<10	NA
34.	Methyl ethyl ketone	200 - 240(600-700)[c]	NA	<50[b]	NA	<50(460-1100)[c]	NA
Semivolatile organics							
220.	Phthalic acid (used as a surrogate for phthalic anhydride)	13,000 - 220,000	NA	<160[b]	NA	<8.2[d]	NA
	Anthracene dione[e]	5,400 - 6,700	NA	<250[b]	NA	<2.5	NA
Metals							
155.	Arsenic	NT	NT	<0.020-0.22	NA	2.1 - 12	<1.5
156.	Barium	NT	NT	<0.010-0.41	NA	35 - 3900	0.084- 0.38
158.	Cadmium	NT	NT	<0.020-0.082	NA	<1.5 - 2.2	0.004-<0.015
159.	Chromium	NT	NT	<0.035-0.65	NA	20 - 52	0.004- 0.37
160.	Copper	NT	NT	<0.030-0.81	NA	21 - 46	<0.05 - 0.14
161.	Nickel	NT	NT	<0.075-0.13	NA	11 - 55	<0.10 - 1.5
163.	Lead	NT	NT	1.4 - 16	NA	20 - 1100	<0.25 - 2.3
166.	Thallium	NT	NT	NT	NA	1.0	0.17 -<0.45
168.	Zinc	NT	NT	0.33 -2.1	NA	29 - 170	<0.10 - 1.6

NA = Not applicable.

NT = Not tested.

[a] BDAT constituent number.

[b] part per billion (ppb)

[c] Numbers given in parenthesis are for methanol extraction procedure where the reading for methyl ethyl ketone is reported to be 770 ppm. Other methyl ethyl ketone values are for tetraglyme extract.

[d] Memo to Fred Hall, PEI Associates, Cincinnati, Ohio, from Patrick Meehan, Radian Corporation, Austin, Texas, dated December 15, 1987.

[e] Non BDAT parameter.

Reference: EPA 1987b, Table 6-3 to 6-6, 6-8 to 6-11, 6-12, 6-13, and 6-14.

7. CALCULATION OF BDAT TREATMENT STANDARDS

In this section, actual performance of best demonstrated available technology for the regulated constituent, phthalic anhydride, is evaluated to calculate a treatment standard. Development of BDAT treatment standards requires a step-by-step approach. Different engineering and analytical steps and statistical methods discussed in Section 1 contribute to this final step of BDAT treatment standards development. The Agency chooses to establish treatment standards as performance levels because this provides the greatest flexibility in meeting the treatment standards. When treatment standards are set as performance levels, the regulated community may use any technology except dilution (prohibited under 40CFR 268.3) to treat the waste to achieve the proposed performance levels.

The treatment standards are also applicable to those wastes regulated as "mixture" and "derived from" wastes. Hence, the treatment standards apply to all nonwastewaters and wastewaters derived from or mixed with the specific waste code.

The BDAT treatment standards (1) are reflective of treatment data for well-designed and well-operated treatment systems; (2) account for analytical deficiencies due to masking, interference, or deviation from the recommended analytical procedures; and (3) adjust for variability due to treatment, sampling, and analytical techniques and procedures.

The BDAT treatment standard for K024 was developed in the following manner using actual performance data for rotary kiln incineration.

7.1 Evaluation of the Performance Data

All the data collected by the Agency for the development of treatment standards were evaluated to determine (a) whether any of the data represented poor design or operation of the treatment system; (b) whether data quality objectives were met; and (c) whether any data sets were homogeneous, i.e., indicated that more than one treatment technology achieved the same level of treatment.

7.2 Calculation of Treatment Standards

Treatment standards are calculated using recovery (accuracy) and precision data generated as part of laboratory QA/QC procedure. All the relevant data are presented in Appendix B. Because there were no quality assessments such as matrix spikes and duplicates specifically for phthalic anhydride (or phthalic acid) the accuracy-corrected concentrations are calculated using the matrix spike data for other semivolatile organics such as 1,2,4-trichlorobenzene, acenaphthene, 2,4-dinitrotoluene, pyrene, 1,4-dichlorobenzene, and N-Nitrosodin-n-propylamine. The spike recovery and spike recovery (duplicate) values were averaged for these constituents to obtain an accuracy factor. Table 7-1 presents the accuracy-corrected concentration for the regulated constituent in each of the residue streams.

EPA recognizes that some BDAT metals were detected in the residue wastewater and nonwastewater from incineration. At this time, the Agency has decided not to regulate metals in the waste, but reserves the right to consider regulation of BDAT metals in the future.

Also shown in Table 7-1 is a variability factor used to derive a treatment standard for K024 waste. See Appendix A for derivation of the variability factor.

Table 7-1 Calculation of BDAT Treatment Standards for K024

Constituent	Concentration in treated waste	Accuracy factor	Average accuracy-corrected concentration	Variability[a] factor	BDAT treatment standard
Phthalic acid[b] in nonwastewater (ash)	<8.2 ppm	1.19	9.8 ppm	2.8	27.5 ppm
Phthalic acid[b] in wastewater (scrubber water)	<0.160 ppm	1.2	0.192 ppm	2.8	0.54 ppm

[a] Variability factor of 2.8 is used when all samples are below the detection limit for the constituent.

[b] Used as a surrogate for phthalic anhydride.

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Versar personnel involved in the preparation of this document included Mr. Jerome Strauss, Program Manager; Ms. Rajani Joglekar, Engineering Team Leader; Ms. Justine Alchowiak, Quality Assurance Officer; Mr. David Pepson, Senior Technical Reviewer; Mr. James Morgan, Technical Reviewer; Ms. Juliet Crumrine, Technical Editor; and the Versar secretarial staff, Ms. Linda Gardiner and Ms. Mary Burton.

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APPENDIX A

STATISTICAL METHODS

A.1 F Value Determination for ANOVA Test

As noted in Section 1.2, EPA is using the statistical method known as analysis of variance (ANOVA) to determine the level of performance that represents "best" treatment where more than one technology is demonstrated. This method provides a measure of the differences between data sets.

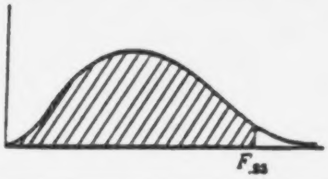
If the Agency found that the levels of performance for one or more technologies are not statistically different (i.e., the data sets are homogeneous), EPA would average the long-term performance values achieved by each technology and then multiply this value by the largest variability factor associated with any of the acceptable technologies. If EPA found that one technology performs significantly better (i.e., the data sets are not homogeneous), the "best" technology would be the technology that achieves the best level of performance, i.e., the technology with the lowest mean value.

To determine whether any or all of the treatment performance data sets are homogeneous using the analysis of variance method, it is necessary to compare a calculated "F value" to what is known as a "critical value." (See Table A-1.) These critical values are available in most statistics texts (see, for example, Statistical Concepts and Methods by Bhattacharyya and Johnson, 1977, John Wiley Publications, New York).

Table A-1

95th PERCENTILE VALUES FOR THE F DISTRIBUTION

n_1 = degrees of freedom for numerator
n_2 = degrees of freedom for denominator
(shaded area = .95)



n_2 \ n_1	1	2	3	4	5	6	8	12	16	20	30	40	50	100	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	246.3	248.0	250.1	251.1	252.2	253.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.43	19.45	19.46	19.46	19.47	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.85	8.74	8.69	8.66	8.62	8.60	8.58	8.56	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.84	5.80	5.75	5.71	5.70	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.60	4.56	4.50	4.46	4.44	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.92	3.87	3.81	3.77	3.75	3.71	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.49	3.44	3.38	3.34	3.32	3.28	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.20	3.15	3.08	3.05	3.03	2.98	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.98	2.93	2.86	2.82	2.80	2.76	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.82	2.77	2.70	2.67	2.64	2.59	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.70	2.65	2.57	2.53	2.50	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.85	2.69	2.60	2.54	2.46	2.42	2.40	2.35	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.77	2.60	2.51	2.46	2.38	2.34	2.32	2.26	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.44	2.39	2.31	2.27	2.24	2.19	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.39	2.33	2.25	2.21	2.18	2.12	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.33	2.28	2.20	2.16	2.13	2.07	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.29	2.23	2.15	2.11	2.08	2.02	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.25	2.19	2.11	2.07	2.04	1.98	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.21	2.15	2.07	2.02	2.00	1.94	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.45	2.28	2.18	2.12	2.04	1.99	1.96	1.90	1.84
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.13	2.07	1.98	1.93	1.91	1.84	1.78
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	2.09	2.03	1.94	1.89	1.86	1.80	1.73
26	4.23	3.37	2.98	2.74	2.59	2.47	2.32	2.15	2.05	1.99	1.90	1.85	1.82	1.76	1.69
28	4.20	3.34	2.95	2.71	2.56	2.45	2.29	2.12	2.02	1.96	1.87	1.81	1.78	1.72	1.65
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.99	1.93	1.84	1.79	1.76	1.69	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.90	1.84	1.74	1.69	1.66	1.59	1.51
50	4.03	3.18	2.79	2.56	2.40	2.29	2.13	1.95	1.85	1.78	1.69	1.63	1.60	1.52	1.44
60	4.00	3.15	2.76	2.53	2.37	2.25	2.10	1.92	1.81	1.75	1.65	1.59	1.56	1.48	1.39
70	3.98	3.13	2.74	2.50	2.35	2.23	2.07	1.89	1.79	1.72	1.62	1.56	1.53	1.45	1.35
80	3.96	3.11	2.72	2.48	2.33	2.21	2.05	1.88	1.77	1.70	1.60	1.54	1.51	1.42	1.32
100	3.94	3.09	2.70	2.46	2.30	2.19	2.03	1.85	1.75	1.68	1.57	1.51	1.48	1.39	1.28
150	3.91	3.06	2.67	2.43	2.27	2.16	2.00	1.82	1.71	1.64	1.54	1.47	1.44	1.34	1.22
200	3.89	3.04	2.65	2.41	2.26	2.14	1.98	1.80	1.69	1.62	1.52	1.45	1.42	1.32	1.19
400	3.86	3.02	2.62	2.39	2.23	2.12	1.96	1.78	1.67	1.60	1.49	1.42	1.38	1.28	1.13
∞	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.64	1.57	1.46	1.40	1.32	1.24	1.00

Where the F value is less than the critical value, all treatment data sets are homogeneous. If the F value exceeds the critical value, it is necessary to perform a "pair wise F" test to determine if any of the sets are homogeneous. The "pair wise F" test must be done for all of the various combinations of data sets using the same method and equation as the general F test.

The F value is calculated as follows:

(i) All data are natural logtransformed.

(ii) The sum of the data points for each data set is computed (T_i).

(iii) The statistical parameter known as the sum of the squares between data sets (SSB) is computed:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^{\,2}}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

where:

k = number of treatment technologies
n_i = number of data points for technology i
N = number of data points for all technologies
T_i = sum of natural logtransformed data points for each technology.

(iv) The sum of the squares within data sets (SSW) is computed:

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2{}_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^{\,2}}{n_i} \right)$$

where:

$x_{i,j}$ = the natural logtransformed observations (j) for treatment technology (i).

(v) The degrees of freedom corresponding to SSB and SSW are calculated. For SSB, the degree of freedom is given by k-1. For SSW, the degree of freedom is given by N-k.

(vi) Using the above parameters, the F value is calculated as follows:

$$F = \frac{MSB}{MSW}$$

where:

$MSB = SSB/(k-1)$ and
$MSW = SSW/(N-k)$.

A computational table summarizing the above parameters is shown below.

Computational Table for the F Value

Source	Degrees of freedom	Sum of squares	Mean square	F value
Between	k-1	SSB	MSB = SSB/k-1	MSB/MSW
Within	N-k	SSW	MSW = SSW/N-k	

Below are three examples of the ANOVA calculation. The first two represent treatment by different technologies that achieve statistically similar treatment; the last example represents a case in which one technology achieves significantly better treatment than the other technology.

Example 1
Methylene Chloride

Steam stripping				Biological treatment			
Influent (µg/l)	Effluent (µg/l)	ln(effluent)	[ln(effluent)]^2	Influent (µg/l)	Effluent (µg/l)	ln(effluent)	[ln(effluent)]^2
1550.00	10.00	2.30	5.29	1960.00	10.00	2.30	5.29
1290.00	10.00	2.30	5.29	2568.00	10.00	2.30	5.29
1640.00	10.00	2.30	5.29	1817.00	10.00	2.30	5.29
5100.00	12.00	2.48	6.15	1640.00	26.00	3.26	10.63
1450.00	10.00	2.30	5.29	3907.00	10.00	2.30	5.29
4600.00	10.00	2.30	5.29				
1760.00	10.00	2.30	5.29				
2400.00	10.00	2.30	5.29				
4800.00	10.00	2.30	5.29				
12100.00	10.00	2.30	5.29				
Sum:							
-	-	23.18	53.76	-	-	12.46	31.79
Sample Size:							
10	10	10	-	5	5	5	-
Mean:							
3669	10.2	2.32	-	2378	13.2	2.49	-
Standard Deviation:							
3328.67	.63	.06	-	923.04	7.15	.43	-
Variability Factor:							
	1.15	-	-	-	2.48	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^{\,2}}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

Example 1 (Continued)

$F = MSB/MSW$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of natural logtransformed data points for all technologies

T_i = sum of logtransformed data points for each technology

X_{ij} = the nat. logtransformed observations (j) for treatment technology (i)

$n_1 = 10,\ n_2 = 5,\ N = 15,\ k = 2,\ T_1 = 23.18,\ T_2 = 12.46,\ T = 35.64,\ T^2 = 1270.21$

$T_1^2 = 537.31 \quad T_2^2 = 155.25$

$$SSB = \left(\frac{537.31}{10} + \frac{155.25}{5}\right) - \frac{1270.21}{15} = 0.10$$

$$SSW = (53.76 + 31.79) - \left(\frac{537.31}{10} + \frac{155.25}{5}\right) = 0.77$$

$MSB = 0.10/1 = 0.10$

$MSW = 0.77/13 = 0.06$

$$F = \frac{0.10}{0.06} = 1.67$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.10	0.10	1.67
Within(W)	13	0.77	0.06	

The critical value of the F test at the 0.05 significance level is 4.67. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 2
Trichloroethylene

Steam stripping				Biological treatment			
Influent (μg/l)	Effluent (μg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$	Influent (μg/l)	Effluent (μg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$
1650.00	10.00	2.30	5.29	200.00	10.00	2.30	5.29
5200.00	10.00	2.30	5.29	224.00	10.00	2.30	5.29
5000.00	10.00	2.30	5.29	134.00	10.00	2.30	5.29
1720.00	10.00	2.30	5.29	150.00	10.00	2.30	5.29
1560.00	10.00	2.30	5.29	484.00	16.25	2.79	7.78
10300.00	10.00	2.30	5.29	163.00	10.00	2.30	5.29
210.00	10.00	2.30	5.29	182.00	10.00	2.30	5.29
1600.00	27.00	3.30	10.89				
204.00	85.00	4.44	19.71				
160.00	10.00	2.30	5.29				

Sum:	-	-	26.14	72.92	-	-	16.59	39.52
Sample Size:	10	10	10	-	7	7	7	-
Mean:	2760	19.2	2.61	-	220	10.89	2.37	-
Standard Deviation:	3209.6	23.7	.71	-	120.5	2.36	.19	-
Variability Factor:	-	3.70	-	-	-	1.53	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i-1}^{k} \sum_{j-1}^{n_i} x^2{}_{i,j} \right] - \sum_{i-1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW - SSW/(N-k)$$

Example 2 (Continued)

$F = MSB/MSW$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 10$, $N_2 = 7$, $N = 17$, $k = 2$, $T_1 = 26.14$, $T_2 = 16.59$, $T = 42.73$, $T^2 = 1825.85$, $T_1^2 = 683.30$,

$T_2^2 = 275.23$

$$SSB = \left(\frac{683.30}{10} + \frac{275.23}{7}\right) - \frac{1825.85}{17} = 0.25$$

$$SSW = (72.92 + 39.52) - \left(\frac{683.30}{10} + \frac{275.23}{7}\right) = 4.79$$

$MSB = 0.25/1 = 0.25$

$MSW = 4.79/15 = 0.32$

$$F = \frac{0.25}{0.32} = 0.78$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.25	0.25	0.78
Within(W)	15	4.79	0.32	

The critical value of the F test at the 0.05 significance level is 4.54. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

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Example 3

Chlorobenzene

Activated sludge followed by carbon adsorption				Biological treatment			
Influent (µg/l)	Effluent (µg/l)	ln(effluent)	[ln(effluent)]^2	Influent (µg/l)	Effluent (µg/l)	ln(effluent)	ln[(effluent)]^2
7200.00	80.00	4.38	19.18	9206.00	1083.00	6.99	48.86
6500.00	70.00	4.25	18.06	16646.00	709.50	6.56	43.03
6075.00	35.00	3.56	12.67	49775.00	460.00	6.13	37.58
3040.00	10.00	2.30	5.29	14731.00	142.00	4.96	24.60
				3159.00	603.00	6.40	40.96
				6756.00	153.00	5.03	25.30
				3040.00	17.00	2.83	8.01
Sum:							
-	-	14.49	55.20	-	-	38.90	228.34
Sample Size:							
4	4	4	-	7	7	7	-
Mean:							
5703	49	3.62	-	14759	452.5	5.56	-
Standard Deviation:							
1835.4	32.24	.95		16311.86	379.04	1.42	
Variability Factor:							
-	7.00	-	-	-	15.79	-	-

ANOVA Calculations:

$$SSB - \left[\sum_{i=1}^{k} \left(\frac{T_i}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2{}_{i,j} \right] \sum_{i=1}^{k} \left(\frac{T_i{}^2}{n_i} \right)$$

MSB = SSB/(k-1)

MSW = SSW/(N k)

F = MSB/MSW

Example 3 (Continued)

where,

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 4$, $N_2 = 7$, $N = 11$, $k = 2$, $T_1 = 14.49$, $T_2 = 38.90$, $T = 53.39$, $T^2 = 2850.49$, $T_1^2 = 209.96$

$T_2^2 = 1513.21$

$$SSB = \left[\frac{209.96}{4} + \frac{1513.21}{7}\right] - \frac{2850.49}{11} = 9.52$$

$$SSW = (55.20 + 228.34) - \left[\frac{209.96}{4} + \frac{1513.21}{7}\right] = 14.88$$

$MSB = 9.52/1 = 9.52$

$MSW = 14.88/9 = 1.65$

$F = 9.52/1.65 = 5.77$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	9.53	9.53	5.77
Within(W)	9	14.89	1.65	

The critical value of the F test at the 0.05 significance level is 5.12. Since the F value is larger than the critical value, the means are significantly different (i.e., they are heterogeneous). Activated sludge followed by carbon adsorption is "best" in this example because the mean of the long-term performance value, i.e., the effluent concentration, is lower.

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

A.2 Variability Factor

$$VF = \frac{C_{99}}{\text{Mean}}$$

where:

VF = estimate of daily maximum variability factor determined from a sample population of daily data;

C_{99} = estimate of performance values for which 99 percent of the daily observations will be below. C_{99} is calculated using the following equation: $C_{99} = \text{Exp}(y + 2.33\ Sy)$ where y and Sy are the mean and standard deviation, respectively, of the logtransformed data; and

Mean = average of the individual performance values.

EPA is establishing this figure as an instantaneous maximum because the Agency believes that on a day-to-day basis the waste should meet the applicable treatment standards. In addition, establishing this requirement makes it easier to check compliance on a single day. The 99th percentile is appropriate because it accounts for almost all process variability.

In several cases, all the results from analysis of the residuals from BDAT treatment are found at concentrations less than the detection limit. In such cases, all the actual concentration values are considered unknown and, hence, cannot be used to estimate the variability factor of the analytical results. Below is a description of EPA's approach for calculating the variability factor for such cases with all concentrations below the detection limit.

It has been postulated as a general rule that a lognormal distribution adequately describes the variation among concentrations. Agency data show that the treatment residual concentrations are distributed approximately lognormally. Therefore, the lognormal model has been used routinely in the EPA development of numerous regulations in the Effluent Guidelines program and is being used in the BDAT program. The variability factor (VF) was defined as the ratio of the 99th percentile (C_{99}) of the lognormal distribution to its arithmetic mean (Mean), as follows:

$$VF = \frac{C_{99}}{Mean}. \qquad (1)$$

The relationship between the parameters of the lognormal distribution and the parameters of the normal distribution created by taking the natural logarithms of the lognormally distributed concentrations can be found in most mathematical statistics texts (see, for example, Distribution in Statistics-Volume 1 by Johnson and Kotz, 1970). The mean of the lognormal distribution can be expressed in terms of the mean (μ) and standard deviation (σ) of the normal distribution as follows:

$$C_{99} = \text{Exp}\ (\mu + 2.33\sigma) \qquad (2)$$
$$\text{Mean} = \text{Exp}\ (\mu + 0.5\sigma^2). \qquad (3)$$

By substituting (2) and (3) in (1), the variability factor can then be expressed in terms of σ as follows:

$$VF = \text{Exp}\ (2.33\ \sigma - 0.5\sigma^2). \qquad (4)$$

For residuals with concentrations that are not all below the detection limit, the 99th percentile and the mean can be estimated from the actual analytical data and, accordingly, the variability factor (VF) can be estimated using equation (1). For residuals with concentrations that are below the detection limit, the above equations can be used in conjunction with the following assumptions to develop a variability factor.

- Assumption 1: The actual concentrations follow a lognormal distribution. The upper limit (UL) is equal to the detection limit. The lower limit (LL) is assumed to be equal to one-tenth of the detection limit. This assumption is based on the fact that data from well-designed and well-operated treatment systems generally fall within one order of magnitude.

- Assumption 2: The natural logarithms of the concentrations have a normal distribution with an upper limit equal to ln (UL) and a lower limit equal to ln (LL).

- Assumption 3: The standard deviation (σ) of the normal distribution is approximated by:

  $$\begin{aligned}\sigma &= [\ln(UL) - \ln(LL)] / [(2)(2.33)] \\ &= [\ln(UL/LL)] / 4.66. \qquad (5)\end{aligned}$$

  (Note that when LL = (0.1)(UL) as in Assumption 1, then $\sigma = (\ln 10) / 4.66 = 0.494.$)

Substitution of the σ value from equation (5) into equation (4) yields the variability factor, VF, as shown:

$$VF = 2.8. \qquad (6)$$

APPENDIX B

ANALYTICAL QA/QC

Quality assurance/quality control (QA/QC) measures taken during the test are outlined in this appendix.

B.1 Volatile Organic Compounds

The volatile samples were analyzed according to the QA/QC procedures outlined in SW-845 Method 8240, 3rd ed. Calibration of the instrument was demonstrated daily with PFTBA to give an acceptable spectrum of BFB.*

System performance was verified initially (beginning with 5-point calibrations) to ensure a minimum average response factor of 0.3 (0.25 for bromoform) for the following system performance check compounds (SPCCs):

- Chloromethane
- 1,1-Dichloroethane
- Bromoform
- 1,1,2,2-Tetrachloroethane
- Chlorobenzene

Adherence to these criteria was demonstrated every 12 hours for the duration of the project.

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*PFTBA, perfluorotributylamine; BFB, bromofluorobenzene.

For analyte calibration, the initial 5-point calibration of 5, 10, 50, 100, and 200 μg/liter standards, used for generating response factors, also demonstrated a percent relative standard deviation (% RSD) of less than 30 for all of the following calibration check compounds (CCC's):

- 1,1-Dichloroethene
- Chloroform
- 1,2-Dichloropropane
- Toluene
- Ethylbenzene
- Vinyl chloride

Adherence to this criterion was also demonstrated every 12 hours for the duration of the project.

A sample from each matrix type was used to perform duplicate matrix spike analyses. Each sample was spiked with 125 ng of the following matrix spike compounds as per EPA SW-846, 3rd ed:

- 1,1-Dichloroethene
- Trichloroethene
- Toluene
- Benzene

Tables B-1 through B-5, at the end of this appendix, show the accuracy and precision of these analyses. The percentage recoveries of the spikes for 1,1-dichloroethylene in the scrubber effluent are outside acceptable limits. All other sample recoveries are within the specified target limits, as are the relative percent differences.

B.2 Semivolatile Organic Compounds

All semivolatile extracts were analyzed by the QA/QC procedures outlined in SW-846 Method 8270, 3rd edition, without significant modification. The mass spectrometer used for these analyses (see Table B-1) was tuned daily by PFTBA. The stability of this tune was verified by demonstrating an acceptable spectrum of decafluorotriphenylphosphine (DFTPP) daily (or every 12 hours). Acceptable chromatography was verified daily by examining the peak shape of benzidine and pentachlorophenol.

System performance was verified daily, beginning with the 5-point calibration, by demonstrating that system performance check compounds (SPCCY's) had response factors greater than 0.05 when using the 50 μg/ml calibration standard. These SPCCs were:

- N-nitrosodi-n-propylamine
- Hexachlorocyclopentadiene
- 2,4-Dichlorophenol
- 4-Nitrophenol

For continuing analyte calibration, three 5-point calibrations were generated during the course of this work with Appendix IX standards at 10, 20, 50, 100, and 200 μg/ml concentrations. Specific ion response factors for the following calibration check compounds (CCCs) were verified to have less than 30 percent relative standard deviation over the range calibrated:

- Phenol
- 1,4-Dichlorobenzene
- 2-Nitrophenol
- 2,4-Dichlorophenol
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol
- Acenaphthene
- 2,4,6-Trichlorophenol
- N-nitrosodiphenylamine
- Pentachlorophenol
- Fluoranthene
- Di-n-octylphthalate
- Benzo(a)pyrene

These CCCs were reanalyzed every 12 hours to verify that the response factor remained within ±30 percent of that generated from the average of the 5-point standard.

For duplicate matrix spike analyses, a sample from each matrix type was used to perform duplicate matrix spike analyses. Samples were spiked prior to extraction with a mixture containing the following:

- 1,2,4-Trichlorobenzene
- Acenaphthene
- 2,4-Dinitrotoluene
- Pyrene
- 1,4-Dichlorobenzene
- N-nitrosodi-n-propylamine
- Pentachlorophenol
- Phenol
- 2-Chlorophenol
- 4-Chloro-3-methyl phenol
- 4-Nitrophenol

The accuracy and precision of these analyses are shown in Tables B-6 through B-13.

B.3 Metals and Other Parameters

All samples were analyzed according to the QA/QC procedures outlined in the appropriate methods listed in Section 1. All instruments were calibrated daily with freshly prepared standards.

System performance was verified immediately after calibration with a calibration verification standard prepared from a different source. When applicable, an NBS or EPA Quality Assurance sample is used for this purpose. This standard is then analyzed at 10 percent intervals throughout the analysis and at the end of the analytical run to verify system control. For all parameters, the recoveries for the calibration verification standards analyzed throughout this project were between 86 and 111 percent.

Ash sample number CK-24-3-B1 was used for the duplicate matrix spike analysis. These data are presented in Table B-14. Precision, as measured by relative percent difference, is <20 percent on all of these analyses, which is the acceptance limit required for this project. Accuracy (percent recovery) for the metals analyzed by ICP is within the acceptance range of 75 to 125 percent. Recovery of the elements by atomic absorption is lower than the ICP acceptance limits. Other parameters (instrument checks, calibration, and check samples) were within range for these analyses, which indicates that a matrix effect was the cause of these low recoveries. Analyses by graphite furnace atomic absorption for arsenic, selenium, and thallium are more sensitive than those using the ICP methods, but they are also more prone to physical and chemical matrix interferences.

Table B-1 Volatiles Spike Recovery (Accuracy) and Relative Percent Difference (Precision) for Scrubber Sample

Matrix spike	Determined concentration (µg/liter) CK24-2-D2 43532	 CK24-2-D2 43533	 CK24-2-D2 43534	Percent spike recovery	Percent spike recovery duplicate	Relative percent difference
Benzene	ND[a]	28	28	112	112	0
Chlorobenezene	ND	30	29	120	116	3
1,1-Dichloroethylene	ND	45	41	180	164	9
Toluene	ND	29	29	116	116	0
Trichloroethene	ND	21	20	84	80	5

[a] ND = Not detected

Table B-2 Volatiles Spike Recovery (Accuracy) and Relative Percent Difference (Precision) for Tetraglyme Extract of Feed Sample

Matrix spike	Determined concentration (µg/liter) CK24-1-AX 43651	 CK24-1-AX 43728	 CK24-1-AX 43729	Percent spike recovery	Percent spike recovery duplicate	Relative percent difference
Benzene	2	29	29	116	116	0
Chlorobenezene	ND[a]	28	29	112	116	4
1,1-Dichloroethylene	ND	28	27	112	108	4
Toluene	ND	29	29	116	116	0
Trichloroethene	ND	22	21	88	84	5

[a] ND = Not detected

Table B-3 Volatiles Spike Recovery (Accuracy) and Relative Percent Difference (Precision) for Tetraglyme Extract of Ash Sample

Matrix spike	Determined concentration (µg/liter) CK24-2-B1 43650	CK24-2-B2 43658	CK24-2-B2 43659	Percent spike recovery	Percent spike recovery duplicate	Relative percent difference
Benzene	3	29	29	104	104	0
Chlorobenezene	ND[a]	28	28	112	112	0
1,1-Dichloroethylene	ND	35	34	140	136	3
Toluene	2	33	29	122	107	13
Trichloroethene	ND	26	27	104	108	4

[a] ND = Not detected.

Table B-4 Volatiles Spike Recovery (Accuracy) and Relative Percent Difference (Precision) for TCLP Extract of Feed Sample

Matrix spike	Determined concentration (µg/liter) CK24-3-AX 43634	CK24-3-AX-1 43645	CK24-3-AX-1 43646	Percent spike recovery	Percent spike recovery duplicate	Relative percent difference
Benzene	6	32	31	103	100	3
Chlorobenezene	ND[a]	27	26	108	104	4
1,1-Dichloroethylene	ND	35	38	140	152	8
Toluene	7	30	27	94	84	11
Trichloroethene	ND	27	27	108	108	0

[a] ND = Not detected

Table B-5 Volatiles Spike Recovery (Accuracy) and Relative Percent Difference (Precision) for TCLP Extract of Ash Sample

Matrix spike	Determined concentration (µg/liter)			Percent spike recovery	Percent spike recovery duplicate	Relative percent difference
	CK24-2-B1-1 43632	CK24-2-B2-1 43633	CK24-2-B2-4 43634			
Benzene	2	28	29	104	107	4
Chlorobenezene	ND[a]	30	27	120	108	11
1,1-Dichloroethylene	ND	31	36	124	144	15
Toluene	2	29	28	107	104	4
Trichloroethene	ND	28	26	112	104	7

[a] ND = Not detected

Table B-6 Semivolatiles Matrix Spike Extract Surrogate Recoveries (%)

Surrogate	CK24-2-D3	CK24-2-D3	CK24-2-AX	CK24-2-AX	CK24-1-B1	CK24-1-B1	CK24-3-AX	CK24-3-AX	CK24-2-B1	CK24-2-B1
2-Fluorophenol	21	26	108	105	95	90	78	63	89	64
Phenol-d5	30	32	111	104	94	92	85	64	90	64
Nitrobenzene-d5	92	92	111	105	99	96	80	86	75	71
2-Fluorobiphenyl	67	65	75	69	67	68	57	61	42	42
2,4,6-Tribromophenol	49	51	87	80	77	81	73	76	75	46
Terphenyl-d14	100	102	112	111	103	104	87	91	89	69

Table B-7 Semivolatiles Laboratory Check Standard
Extract Surrogate Recoveries (%)

Surrogate	Run 1 35993	Run 2 36053	Run 3 36055	Run 4 36056
2-Fluorophenol	78	62	71	70
Phenol-d5	78	64	77	76
Nitrobenzene-d5	85	74	82	84
2-Fluorobiphenyl	55	49	54	55
2,4,6-Tribromophenol	52	44	55	57
Terphenyl-d14	100	94	99	100

Table B-8 Semivolatiles Matrix Spike Recovery (Accuracy) and Relative Difference (Precision) for Scrubber Effluent Sample

(B/N = 50 µg/ml) Matrix spike (Acids = 100 µg/ml)	Determined concentration (µg/liter)			Spike recovery (%)	Spike recovery duplicate (%)	Relative percent difference (%)
	CK24-2-D3	CK24-2-D3	C24-2-D3			
1,2,4-Trichlorobenzene	ND	36	36	72	72	0
Acenaphthene	ND	48	49	96	98	2
2,4-Dinitrotoluene	ND	57	60	114	120	5
Pyrene	ND	49	50	98	100	3
1,4-Dichlorobenzene	ND	34	34	68	68	0
N-Nitrosodi-n-propylamine	ND	21	22	42	44	5
Pentachlorophenol	ND	60	64	60	64	6
Phenol	ND	36	34	36	34	6
2-Chlorophenol	ND	49	46	49	46	6
4-Chloro-3-methylphenol	ND	49	47	49	47	4
4-Nitrophenol	ND	77	90	77	90	16

ND = Not detected.

Table B-9 Semivolatiles Matrix Spike Recovery (Accuracy) and Relative Difference (Precision) for Feed Sample

(B/N = 50 μg/ml) Matrix spike (Acids = 100 μg/ml)	Determined concentration (μg/liter)			Spike recovery (%)	Spike recovery duplicate (%)	Relative percent difference (%)
	CK24-2-AX	CK24-2-AX	C24-1-B1			
1,2,4-Trichlorobenzene	ND	54	50	108	100	8
Acenaphthene	ND	53	50	106	100	6
2,4-Dinitrotoluene	ND	64	60	128	120	6
Pyrene	ND	49	44	98	88	11
1,4-Dichlorobenzene	ND	52	49	104	98	6
N-Nitrosodi-n-propylamine	ND	27	24	54	48	12
Pentachlorophenol	ND	104	93	104	93	11
Phenol	ND	106	106	106	106	0
2-Chlorophenol	ND	123	119	123	119	3
4-Chloro-3-methylphenol	ND	95	92	95	92	3
4-Nitrophenol	ND	123	116	123	116	6

ND = Not detected.

Table B-10 Semivolatiles Matrix Spike Recovery (Accuracy) and Relative Difference (Precision) for Ash Sample

Matrix spike (Acids = 100 μg/ml) (B/N = 50 μg/ml)	Determined concentration (μg/liter) CK24-1-B1	CK24-1-B1	C24-1-B1	Spike recovery (%)	Spike recovery duplicate (%)	Relative percent difference (%)
1,2,4-Trichlorobenzene	ND	45	45	90	90	0
Acenaphthene	ND	48	48	96	96	0
2,4-Dinitrotoluene	ND	59	59	118	118	0
Pyrene	ND	47	41	94	82	14
1,4-Dichlorobenzene	ND	45	45	89	90	1
N-Nitrosodi-n-propylamine	ND	20	13	40	26	42
Pentachlorophenol	ND	98	91	98	91	7
Phenol	ND	96	94	96	94	2
2-Chlorophenol	ND	109	107	109	107	2
4-Chloro-3-methylphenol	ND	88	86	88	86	2
4-Nitrophenol	ND	120	114	120	114	5

ND = Not detected.

Table B-11 Semivolatiles Matrix Spike Recovery (Accuracy) and Relative Difference (Precision) for Feed TCLP Extract

(B/N = 50 μg/ml) Matrix spike (Acids = 100 μg/ml)	Determined concentration (μg/liter)			Spike recovery (%)	Spike recovery duplicate (%)	Relative percent difference (%)
	CK24-3-AX	CK24-3-AX	C24-3-AX			
1,2,4-Trichlorobenzene	ND	22	21	88	84	5
Acenaphthene	ND	24	23	96	92	4
2,4-Dinitrotoluene	ND	31	32	124	128	3
Pyrene	ND	32	24	128	96	29
1,4-Dichlorobenzene	ND	21	21	84	84	0
N-Nitrosodi-n-propylamine	ND	26	27	104	108	4
Pentachlorophenol	11	32	28	84	64	27
Phenol	8	33	27	100	76	27
2-Chlorophenol	ND	24	23	96	96	0
4-Chloro-3-methylphenol	ND	23	23	96	96	0
4-Nitrophenol	ND	32	22	128	88	37

ND = Not detected.

Table B-12 Semivolatiles Matrix Spike Recovery (Accuracy) and Relative Difference (Precision) for Ash TCLP Extract

(B/N = 50 μg/ml) Matrix spike (Acids = 100 μg/ml)	Determined concentration (μg/liter)			Spike recovery (%)	Spike recovery duplicate (%)	Relative percent difference (%)
	CK24-2-B1	CK24-2B-1	C24-2-B1			
1,2,4-Trichlorobenzene	ND	21	19	84	76	10
Acenaphthene	ND	24	20	96	80	18
2,4-Dinitrotoluene	ND	23	15	92	60	42
Pyrene	ND	22	16	88	64	32
1,4-Dichlorobenzene	ND	20	19	80	76	5
N-Nitrosodi-n-propylamine	ND	26	21	104	84	21
Pentachlorophenol	ND	14	10	56	40	33
Phenol	ND	24	19	96	76	23
2-Chlorophenol	ND	24	20	96	80	18
4-Chloro-3-methylphenol	ND	20	16	80	64	22
4-Nitrophenol	ND	23	8	92	32	97

ND = Not detected.

Table B-13 Semivolatiles Laboratory Check Standard Results

Analyte (true concentration)	Determined concentration (μg/liter with percent error) Run 1 35993	Run 2 36053	Run 3 36055	Run 4 36056	Mean (% error)	Precision (% RSD)
1,2,4-Trichlorobenzene (50.7)	41.6 (18%)	41.7 (18%)	39.8 (18%)	41.5 (18%)	41.2 (18%)	2.2%
Pentachloronitrobenzene (74.5)	56.2 (25%)	61.1 (18%)	62.9 (16%)	64.8 (13%)	61.3 (18%)	6.0%

Table B-14 Duplicate Matrix Spike Data for Metals Analysis of Ash Sample CK-24-3-B1

CK-24-3-B1	CK-24-3-B1 (µg/g)	MS CK-24-3-B1 (%)	MSD difference (%)	Relative percent Analyte (%)
Silver	ND	89	88	1
Arsenic	2.1	51[a]	46[a]	10
Barium	35	81	91	12
Beryllium	ND	86	85	1
Cadmium	ND	87	84	4
Chromium	52	90	97	7
Copper	21	91	84	8
Mercury	ND	115	105	9
Nickel	55	89	99	11
Lead	20[b]	90	90	0
Antimony	ND	106	98	8
Selenium	ND	0[a]	0	[c]
Thallium	ND	65[a]	69	6
Vanadium	9[b]	87	88	1
Zinc	29	84	82	2

ND = Not detected.

[a] Data outside of QC/QA limits for this analysis.

[b] Amount is less than five times detection limit.

[c] Not calculated.

APPENDIX C

METHOD OF MEASUREMENT FOR THERMAL CONDUCTIVITY

The comparative method of measuring thermal conductivity has been proposed as an ASTM test method under the name "Guarded, Comparative, Longitudinal Heat Flow Technique." A thermal heat flow circuit is used that is the analog of an electrical circuit with resistances in series. A reference material is chosen to have a thermal conductivity close to that estimated for the sample. Reference standards (also known as heat meters) having the same cross-sectional dimensions as the sample are placed above and below the sample. An upper heater, a lower heater, and a heat sink are added to the "stack" to complete the heat flow circuit. See Figure C-1.

The temperature gradients (analogous to potential differences) along the stack are measured with type K (chromel/alumel) thermocouples placed at known separations. The thermocouples are placed into holes or grooves in the references and also in the sample whenever the sample is thick enough to accommodate them.

For molten samples, pastes, greases, and other materials that must be contained, the material is placed into a cell consisting of a top and bottom of Pyrex 7740 and a containment ring of marinite. The sample is 2 inches in diameter and 0.5 inch thick. Thermocouples are not placed into the sample; rather, the temperatures measured in the Pyrex are extrapolated to give the temperature at the top and bottom surfaces of the sample material. The Pyrex disks also serve as the thermal conductivity reference material.

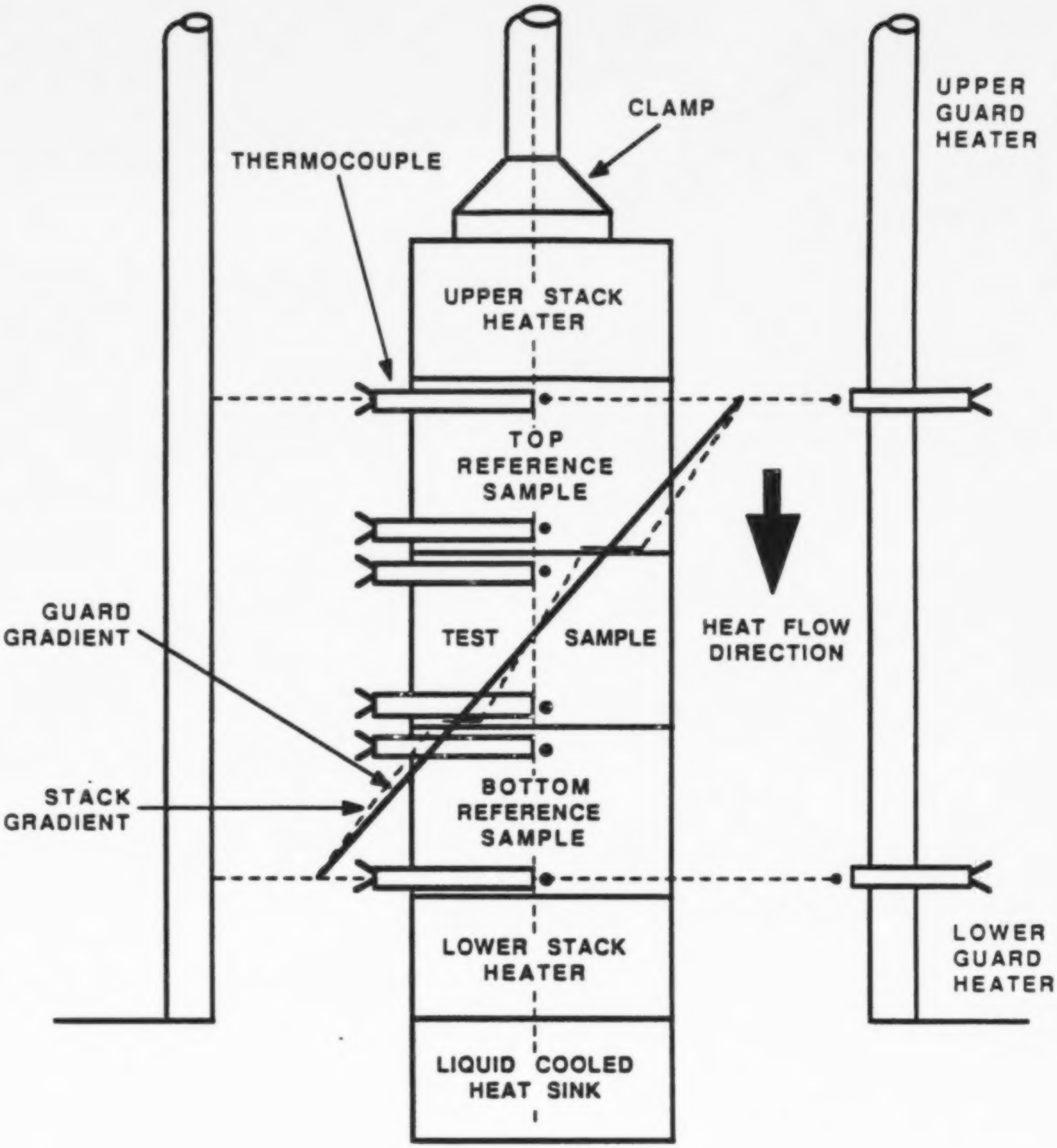
UPPER GUARD HEATER
CLAMP
THERMOCOUPLE
UPPER STACK HEATER
TOP REFERENCE SAMPLE
HEAT FLOW DIRECTION
GUARD GRADIENT
TEST SAMPLE
STACK GRADIENT
BOTTOM REFERENCE SAMPLE
LOWER STACK HEATER
LOWER GUARD HEATER
LIQUID COOLED HEAT SINK

FIGURE C-1 SCHEMATIC DIAGRAM OF THE COMPARATIVE METHOD

The stack is clamped with a reproducible load to ensure intimate contact between the components. To produce a linear flow of heat down the stack and reduce the amount of heat that flows radially, a guard tube is placed around the stack, and the intervening space is filled with insulating grains or powder. The temperature gradient in the guard is matched to that in the stack to further reduce radial heat flow.

The comparative method is a steady-state method of measuring thermal conductivity. When equilibrium is reached, the heat flux (analogous to current flow) down the stack can be determined from the references. The heat into the sample is given by

$$Q_{in} = \lambda_{top} (dT/dx)_{top}$$

and the heat out of the sample is given by

$$Q_{out} = \lambda_{bottom} (dT/dx)_{bottom}$$

where

λ = thermal conductivity

dT/dx = temperature gradient

and top refers to the upper reference, while bottom refers to the lower reference. If the heat were confined to flow down the stack, then Q_{in} and Q_{out} would be equal. If Q_{in} and Q_{out} are in reasonable agreement, the average heat flow is calculated from

$$Q = (Q_{in} + Q_{out})/2.$$

The sample thermal conductivity is then found from

$$\lambda_{sample} = Q/(dT/dx)_{sample}.$$